SCo. Report No. - 2123-5.4-4-1

7045 3

Levingston

TECHNOLOGY TRANSFER PROGRAM (TTP)

FINAL REPORT

STANDARDS

STANDARDS
VOLUME 1 REPORT

Prepared by:

Livingston Shipbuilding Company
in conjunction with:
IHI Marine Technology, Inc.

June 30, 1981

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 JUN 1981**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE
Technology Transfer Program (TTP) Standards Volume 1 Report

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128-9500 MacArthur Blvd Bethesda, MD 20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**185**	

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PREFACE

This report is one of several emanating from the Shipbuilding Technology Transfer Program performed by Livingston Shipbuilding Company under a cost sharing contract with the U.S. Maritime Administration.

The material contained herein was developed from the study of the standardization program presently in operation in the shipyards of Ishikawajima-Harima Heavy Industries (IHI) of Japan. Information for this study was derived from source documentation supplied by IHI, information obtained directly from IHI consulting personnel assigned on-site at Livingston, and from personal observations by two teams of Livingston personnel of actual operations at various IHI shipyards in Japan.

In order to place this study in context within the overall Technology Transfer Program, a brief overview of the program and its organization is provided in the following paragraphs:

THE TECHNOLOGY TRANSFER PROGRAM (TTP)

The U. S. shipbuilding industry is well aware of the significant shipbuilding cost differences between the Japanese and ourselves. Many reasons have been offered to explain this differential and whether the reasons are valid or not, the fact remains that Japanese yards are consistently able to offer ships at a price of one-half to two-thirds below U. S. prices.

Seeing this tremendous difference first hand in-their own estimate of a bulk carrier slightly modified from the IHI Future 32 class design, Livingston management determined to not only find out why this was true but to also attempt to determine precise differences between IHI and Livingston engineering and design practices; production planning and control methods; facilities, production processes, methods and techniques; quality assurance methods; and personnel organization, operations and training. The obvious objective of such studies was to identify, examine and implement the Japanese systems, methods and processes which promised a significant improvement in the Levingston design/production process.

With this objective in mind, and recognizing the potential application of the TTP results to the American shipbuilding industry, Levingston initiated a cost-sharing contract with MarAd to provide documentation and industry seminars to reveal program findings and production improvement results measured during production of the bulkers. Subsequently, Livingston subcontracted with IHI Marine Technology Inc. (an American corporation and a subsidiary of IHI, Japan) specifying the areas to be explored and the number and type of IHI consulting personnel required during the period of re-design and initial construction of the first bulker.

Basically, the program is organized into six major tasks:

1 - Cost Accounting .

2 - Engineering and Design

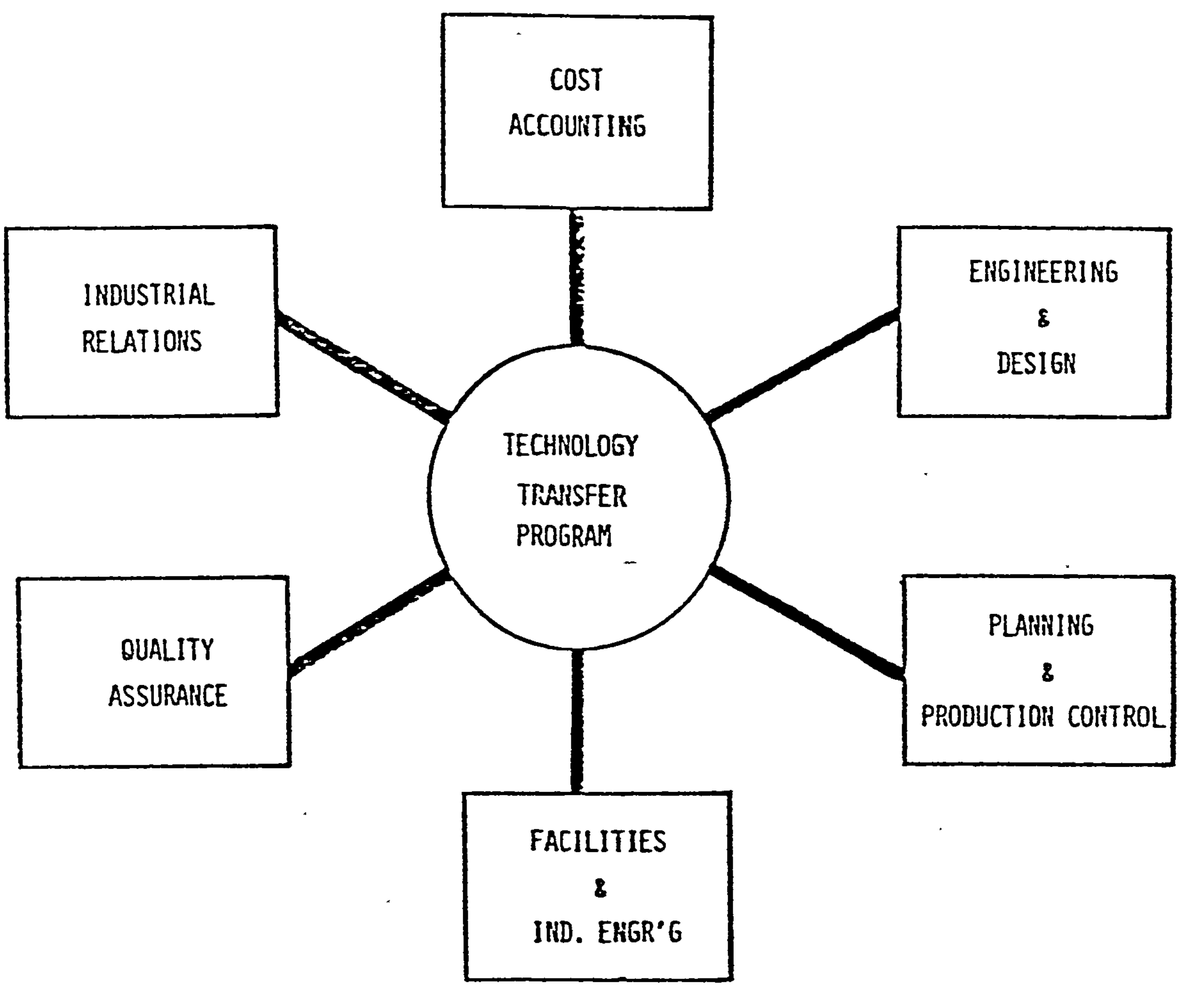
3 - Planning and Production Control

4 - Facilities and Industrial Engineering

5 - Quality Assurance

6 - Industrial Relations

beneath each of these major tasks is a series of sub-tasks which further delineate discrete areas of investigation and study. Each sub-task area has been planned and scheduled to: 1) study IHI systems, methods and techniques; 2) compare the Livingston and IHI practices; 3) identify improvements to the Livingston systems; 4) implement approved changes; 5) document program findings, changes to the Livingston systems, and me results of those changes; and 6) disseminate program findings and results to industry via MarAd.



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SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this study was to analyze the Japanese (IHI) concept of Standards and their application in the actual working environment in IHI shipyards. As in the many other areas of study within the Technology Transfer Program (TTP), the objective of the study was to define possible beneficial and cost-saving elements or methodologies which could be instituted in Livingston and in other medium-size shipyards in the United States.

It was originally intended that the examination of standards would be performed in a number of separate areas within the various tasks, i.e., design and material standards in Task 2, process and cost standards in Task 4, and tolerance standards in Task 5. Early findings, however, revealed that the Japanese approach to standards, like their approach to planning and production control, -is that standards–and standardization are key features of their overall management philosophy and not merely aspects of different areas of activity. The separate components of the study of standards were therefore brought together to be studied as a single system.

1.2 PRINCIPLES OF STANDARDIZATION

Everyone today recognizes the values of standardization. Virtually every handbook or textbook on manufacturing systems contains a chapter or section on standardization and the benefits that result therefrom. This study revealed no new technology, but like other reports in this series, it does reveal a superior achievement in the’ application of known standardization techniques and methods within the marine industry.

IHI philosophy is that manufacturing plants exist to produce specific products. The design of the facility and the work methods employed are determined by that product. Any large scale standardization effort must therefore begin in the design stage. Because the associated manufacturing facilities already exist, standardization of design must be accomplished in harmony with production limitations and capabilities. An often-heard phrase during the TTP was “everything starts in Design and ends in Design”. This is IHI’s way of saying that decisions emanating from Design affect everyone and everything and that feedback to Design is necessary so that Design is cognizant of and responsive to the needs of the production departments. The bottom line is “cost with quality” and every department is responsible.

From standardization of the product, the effort expands. Material is coded, vendors selected, material purchased, production plans determined, and schedules set. For each activity, hundreds of pieces of information pass through the system. Information, though, as conmmunication engineers have determined, consists of two parts: that which is identical to previous information and that which is changed. True information is only that which has changed and standardization minimizes the number of changes. The opportunity to reduce the amount of data handled at every level in the manufacturing process depends directly on the extent of standardization. Reduction in data handled also reduces the occurrence of errors and misunderstandings.

Counter to rigid standardization is the need for flexibility to accommodate customer requirements and changing technology. The compromise is to structure the information (the ship design, plans, schedules, etc.) in such a way that changes in one area have a minimum ripple effect throughout the system. Defining the range of possibilities in a design in terms of only-a few modules or options is an often-used technique. Production schedules, ori the other hand, usually provide slack or buffer time between the completion date at one step and the start date of the next step in order to minimize downstream schedule dislocations due to production problem earlier in the sequence. For both design and production groups, the goal is the same--minimize the changes and isolate the impact of changes that do occur.

Standardization of the product allows the production facilities to be specialized. Economy, through the application of mass production techniques, is well known. TTP reports on Planning and Production Control and Facilities and Industrial Engineering cover details of IHI's implementation of many of these techniques. The development of conveyors, jigs, fixtures, the familiarity of the workers with the equipment, work methods, and ship design are all greatly enhanced as the ship design is standardized.

Facilities are organized in one of_ three ways according to the layout of equipment and the movement of material:

1) Fixed-position layout where the product stays in one position and material is brought to it;

2) Process layout where material is routed to different areas where specialized processes (different for each area) are carried out; and

3) Product flow layout where work-in-progress is moved by conveyor or similar means from one work station to the next.

Shipbuilding uses all three. The last several decades have shown an overall movement from the first and second to the second and third in the attempt to apply mass production technology, i.e., from ship construction to ship production. IHI has made a concerted effort to carry the evolution as far as possible.

The problem still remains that shipbuilding for most shipyards is producing customized products in small lot sizes. American and European manufacturers in other industries have recently introduced the concept of "Group Technology". IHI uses the term to include Family Manufacturing, process-lanes, worker groups, and product-work-breakdown.* A basic component of group technology is the set of requirements imposed on the parts classification and coding system.

This coding leads directly to computerization. In fact, successful computerization of a shipbuilding data base is directly correlated with successes in standardization. Computer-aided design, computer-aided manufacturing (CAD/CAM) and computer-aided process planning (CAPP) all require standardized data in computerized files.

1.3 IHI'S STANDARDIZATION EFFORTS

Overall, IHI views its standardization efforts as:

1) a long range planning effort

2) a means of resolving recurring problems

3) documentation of things learned

4) cost reduction

The paper presented by Y. Ichinose at the University of Michigan entitled "Standardization and Modularization in Shipbuilding" (included as Appendix A) is an excellent summary of the rationale and success of Japan's and IHI's design and material standardization efforts. But the scope of IHI's standardization efforts is much broader. It is no less than *the* standardization of the shipbuilding management process.

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*Throughout the remainder of this report, the term "group technology" is the same as used by IHI.

For any vessel, the ordered set of production processes is the production plan. The myriad of schedules and plans as described in the volumes on Planning and Production Control are a set of procedures. Any document or procedure used repeatedly in essentially the same form becomes a de facto standard. IHI recognizes this and has incorporated this as a basic part of management philosophy permeating all levels of the organization.

Standards are also a tool for communication. Design standards (see Section 2) developed with the aid of production personnel formalize design practices best suited for both design and production. These standards in turn provide “instant experience” to new Personnel. Material standards (see Section 3) are the shorthand notes between Design and Purchasing Departments reducing the volume of descriptive data as well as reducing the variety of materials and supplies maintained in inventory.

In the same way, tolerance standards (see Section 4) provide a clean and definite set of agreements between the design, production, and quality assurance groups. Everyone knows what is required as well as having addressed and settled the questions of how much quality can be. achieved for what cost.

Process standards (see Section 5) cover not only basic marking, cutting, and welding processes but also assembly methods up to and including assembly specification plans which detail the methods to be followed during fabrication, assembly and erection. The most cost effective methods (and alternatives) are documented forming the basis for all future plans.

Having covered the what and the how, cost standards (see Section 6) document the when. All of IHI's long-range and detailed schedules discussed in the volumes on Planning and Production Control depend upon accurate feedback and documentation of the manhour costs from design through delivery. Consistency in product design, consistency in planning methodology, and consistency in production methods lead to greater consistency and lower costs in returned manhours.

From this viewpoint, then, it is clear that the standardization effort is an evolutionary one. Any system must contain within it the means to adapt if it is to survive. For IHI's standards system, the task of continually reviewing, updating old standards, deleting obsolete ones, and creating new standards is recognized as vital and is a basic assignment for all members of the organization.

1.4 APPLICATION OF IHI TECHNOLOGY

Prior to the commencement of the Technology Transfer Program, Levingston was aware of the need for standards and had hoped that some might be directly transferable. During the course of the program the scope and depth of the IHI standardization effort became clear and made a considerable impact.

At the start of the program, a parallel effort was being made by Levingston to reorganize, codify and streamline all phases of documentation. Figure 1-1 illustrates the pyramid structure of that effort. Standards then as now formed the base. This arrangement was overwhelmingly and repeatedly confirmed by the practices and methods utilized by IHI.

Regrettably, few standards (except process stnadards) could be transferred intact into the Levingston system. Differences in major

INTEGRATED HIERARCHY OF DOCUMENTATION

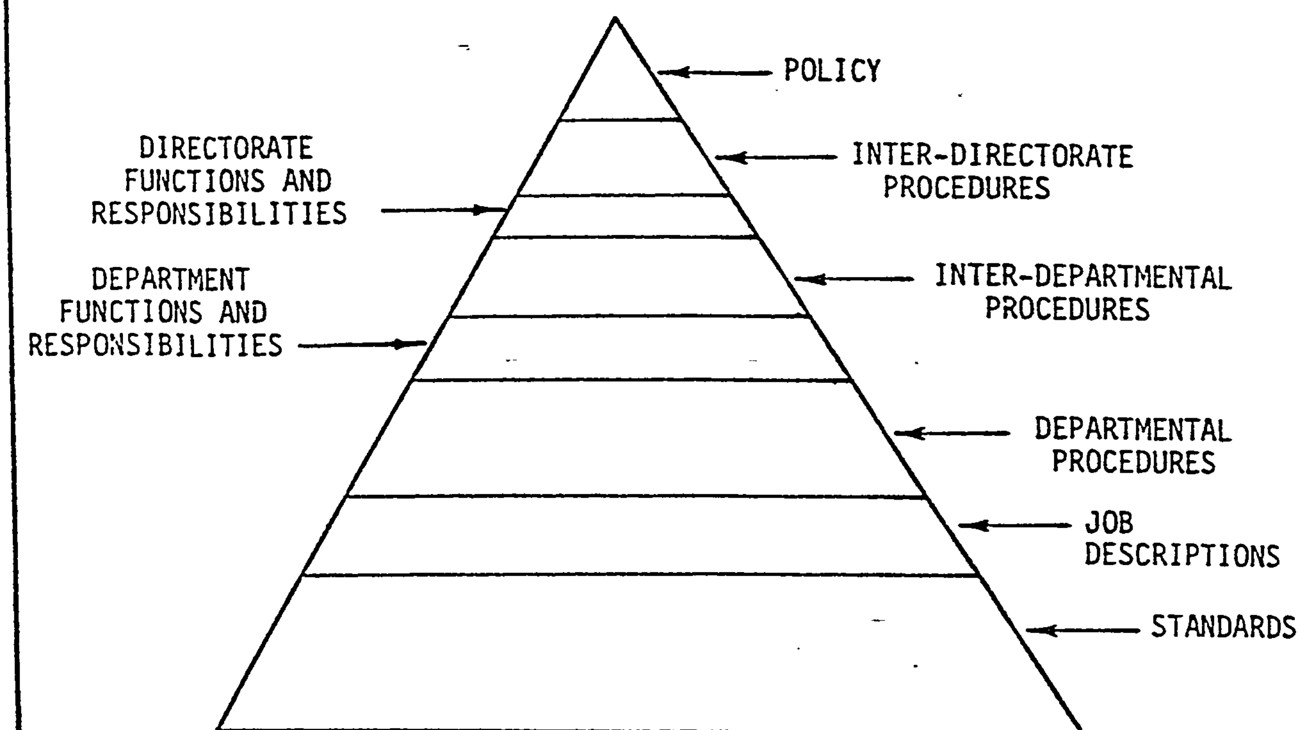

FIGURE 1-1

product, vendor relationships, yard facilities, national standards, measurement systems, and a host of other differences prevented any such direct transfer. But what did transfer was the clear and consistent message of the need for an on-going standardization program. Application was, therefore. directed more toward standards program structure; what should standards cover; documentation; use and so forth. This report reflects that emphasis. lhe working document by which Livingston Standards are being developed is the Standard Operating Procedure for the Initiation, Review and Issuance of Livingston Standards and is included as Appendix G.

1.5 ORGANIZATION OF REPORT

This report comprises two volumes: I - Findings and Conclusions and 11 - Appendices. This volume consists of six sections as follows:

Section 1: Introduction

Section 2: Design Standards

Section 3: Material Standards

Section 4: Tolerance Standards

Section 5: Process Standards

Section 6: Cost Standards

Section 1 contains an overview of the role of standards as a management philosophy and tool. Sections 2 through 6 detail IHI's standardization efforts in specific areas.

A series of appendices are included in Volume 11 of this report that contain data provided by IHI in the course of this program. This appendix material is tied directly to the text in Volume I to clarify by example the points made there. The appendices are listed below:

Appendix

A Standardization and Modularization in Shipbuilding

B JIS Group F Standards on Shipbuilding

C IHI Index of Basic Standards

D Examples of IHI Standards - SOT A221XXX
Hull Structure Material Application

E Examples of IHI Standards - SOT B5XXXXX

F Example of IHI Standards in Use

G Livingston Standard Operating Procedure, "Initiation, Review, and Issuance of Livingston Standards"

Throughout this report reference is made to other reports produced of Livingston in the course of the Technology Transfer Program. A list of these reports is presented below:

Cost Accounting Final Report

Engineering and Design Final Report

Planning and Production Control Final Report

Facilities and Industrial Engineering Final Report

Quality Assurance Final Report

Industrial Relations Final Report

SECTION 2

DESIGN STANDARDS

2.1 INTRODUCTION

Mr. Y. Ichinose’s paper on standardization (Appendix A) shows the extent to which the concepts of standardization have been applied by IHI designers. The philosophical base for the effort was explained by Dr. Hisashi Shinto* as a change in goals by shipyard designers. Prior to the 1950’s, designers were preoccupied with “what better build’’--that is making the ships’ performance better in service. The new approach required designers to consider “how better build’’--that is developing methods for building ships more economically. This change in approach was largely due to 1) experience with mass-produced standardized ships during World ”War II, 2) acquaintance with aircraft design methods which incorporate build methods by shipyards that had built aircraft during World War II, 3) competition in the international market, and 4) introduction of the block assembly methods by E. L. Harm of the National Bulk Carriers, Inc.

This section expands upon the material presented in Appendix A with more details of the structure of IHI standards and their use.

2.2 DEVELOPMENT OF NATIONAL AND SHIPYARD STANDARDS

That a significant difference exists between the role of the governments of Japan and the U. S. in promoting national standards is not new to U. S. shipbuilders. The Japanese Industrial Standardization Law gives that government the authority to select a designated commodity or designated

*President of IHI, in a talk presented before the 1967 Annual Tanker Conference of the American Petroleum Institute.

processing technique for a product. This is done when the quality of the commodity or product must be guaranteed due to its widespread *use* or manufacture.

Figure 2-1 shows the major groupings of the Japanese Industrial Standards (JIS). while many parts of the JIS have been selected as designated commodities or processing techniques, not all are. An index of standards on shipbuilding (Group F) is included as Appendix B. These are consensus standards generated through enthusiastic cooperation within and among professional societies, industrial groups, universities, and agencies of the government.

In much the same way, IHI developed its own set of standards to supplement the JIS. In the early 1960's, a major effort to establish in-house standards was initiated by Dr. Shinto. The merging of the Aioi, Kure, Tokyo, and Nagoya shipyards and establishment of a corporate design office in Tokyo required some form of design standardization. At the same time, early steps in computerization were taking place. Each yard was required to develop standards for all phases of shipyard work. Special task groups were organized in several departments of each yard--Design, Fabrication, Assembly, Erection and Outfitting, etc.--each with the requirement to produce several standards per month. These draft standards were forwarded to headquarters for review and approval. In a typical engineering section, two out of twenty-five engineers were selected. After six months, the assignments were rotated. This was continued over a two-year period at which time about 80 percent of IHI's current standards were identified and draft standards prepared.

2.3 ORGANIZATION AND USE OF IHI DESIGN STANDARDS

The product of the Design Department consists of three parts:

(1) Basic drawings for making the contract

(2) Keyplan for making working drawings

(3) Working drawings for production

Parts (1) and (2) show what is to be built while part (3) shows how to build it. The emphasis on "how better build" is reflected in the number and scope of the working drawings.

The structure for the standards for working drawings is shown in Figure 1 of Appendix A. A general index to the Basic Standards (IS and SOT) is included as Appendix C. The entire Shipbuilding Process and Inspection Standard (SPAIS) is included in the TTP report Quality Assurance, Volume 2.

The Basic Standards are quite detailed. For example, the general index shows 1S-S0 246XXXX Signaling Instruments. The detailed index (Figure 2-2) lists 37 separate standards. Appendix D contains the detailed listing of the Hull Structure Material Application Standard group IS-SOT A221XXX followed by the standards themselves. Appendix E illustrates the IS-SOT B Series, while Appendix F shows how a drawing for a specific ship can be quickly prepared by including "off-the-shelf-standards" -

For the purposes of the TTP, IHI design standards were classified into three categories based on the type of information given:

1) General definition and material coding standards

2) Detailed design standards

3) Production standards

SEAT FOR LIGHT SO-2462XXX

IS-NO	TITLE	QTY	RMKS
2462010E	Stern Light Table (on Handrail Stanchion)	3	
2462030D	Stern Light Table (on Deck)	4	
2462040A	Stern Light Table (with Anchor Light Seat)	3	
2462111B	Screen For Side Light	9	
2462220	Anchor Light Table	2	
2462311B	Mast Head Light Table (on Fore Mast)	4	
2462331B	Range Light Table (on Radar Post)	4	
2462411A	Fitting Seat For Projector (type Pr-f-1)	3	
2462412A	Fitting Seat For Projector (type Pr-f-2)	3	
2462413A	Fitting Seat For Projector (type Pr-f-3)	3	
2462417A	Fitting Seat For Projector (type Pr-d)	6	
2462426A	Fitting Seat For Projector (type Pr-h-1)	5	
2462427	Fitting Seat For Projector (type Pr-h-2)	5	
2462430	Stand for Funnel Projector	3	
2462530A	Fitting Seat For Deck Light (type Bts-1)	5	
2462540A	Fitting Seat For Bot Deck Light (type Bts-s)	5	
2462570A	Fitting Seat For Life Raft Ill. Light (type Lrls)	3	
2462610	Seat For Day Lt Signal Lt (type Dys-1)	4	
2462620	Seat For Day Lt Signal Lt (type Dys-2)	3	
2462910A	Fitting Seat For Shipname Board Light (type Snls)	3	

SIGNAL EQUIPMENT SO-2463XXX

IS-NO	TITLE	QTY	RMKS
2463101A	Ship's Bell	2	
2463103	Black Ball	2	
2463104	Diamond Shape	2	
2463105	Gong	2	
2463106	Fog Horn	4	
2463107	Black Cylinder	2	
2463204	International Signal Flag	8	
2463215A	Flag Hook	2	
2463300A	Navigation Book	6	

OTHERS SO-2469XXX

IS-NO	TITLE	QTY	RMKS
2469100B	Whistle Handle	9	
2469211A	Seat For Whistle Handle (a-type)	2	
2469232	Handle Rest For Whistle Handle (c-type)	2	
2469300A	Lead Sheave Bracket For Whistle Line	2	
2469411A	Penetrating Piece For Whistle Line (on Steel Wall)	2	
2469435	Penetrating Piece For Whistle Line (on Wooden Wall)	2	
2469501	Lead Eye For Whistle Line	3	
2469605B	Sheave And Sheave Pin For Whistle Line	2	

EXCERPT FROM THE GENERAL STANDARDS INDEX

FIGURE 2-2

The standards were also classified by the Livingston Design Section most directly involved: Hull, Piping, Machinery, Electrical, and Joiner. Tables T2-1 through T2-15 list the basic standards used in the comparison.

The development of yard plans from the key plans depends heavily on standardization. The TTP reports entitled Engineering and Design and Planninq and Production Control detail the numerous plans and schedules that must be developed. A detailed schedule of supplying drawings to the yard is prepared as the "Design Procedure and Drawing Supply Schedule" for a particular ship type and is referred to as a "Management Standard".

Much of IHI's success in shipbuilding has been attributed to the detail of the plans and the on-time performance of those who prepare them. There are several methods used to reduce the manhours for drawing preparation:

1) photographic methods whereby reproduced drawings are enhanced with details for specific application

2) computer generated drawings and material lists

3) "off-the-shelf" standards assembled into specific hul l drawings (illustrated in Appendix F)

4) sets of manuals for design and drawing practice

Standards on coding, design practices, production practices, drafting room procedures, material specifications and so forth are reduced in size and bound in book form for ready reference by designers and drafters- Different books are assembled for the separate design sections: hull, piping, machinery, etc. These ready-reference manuals put the shipyard's accumulated experience directly in the hands of those who need it. They also help to ensure uniformity of application within departments and compatibility among departmen ts. In short, standards provide the under pinning to the whole design process.

TABLE T2-1

GENERAL DEFINITION AND MATERIAL CODING FOR HULL

Graphical symbols for welding

Material code guidance for hull part

Name & abbreviation of hull construction

Name & definition of stages for hull construction works

Standards of major block name

Standard of block name (hull unit)

Symbols of hull construction, used for block name

Kind & definition of hull common part

Composition of hull part name

Coding practice of hull parts name

Pre-assembly code for hull parts name

Fabrication code for hull parts name

Stage code for hull parts name

Drawing standard of hull parts table

Style & editing manual of hull structure yard plan

TABLE T2-2

DETAILED DESIGN FOR HULL

Slot & collar plate

Slot & collar plate with butt joint

Slot & collar plate with lap joint

Shape of slot

Clearance between slot and welding joint

Application of transformed slot

Variation of collar plate attached to slot

Fitting side of collar plate

Allowable arrangement of scallop

Standard scallop

Corner cut in case of no scallop

Closing scallop

Water stop welding method

Lightening hole and manhole

Drain & air hole

Step hole

Slot & plug weld

Shape of end connection for stiffener and bracket

TABLE T2-3

PRODUCTION PRACTICE FOR HULL

Drawing practice for temporary holes for construction work

Drawing and application of welding method

Drawing practice of arrangement of plate in midship section

Drawing practice of block arrangement

Drawing practice of fabricating scheme of shell

Weldable limit of narrow space

Molded line details

Decision of moldline (aft and fore parts)

Standard of edge preparation for welding

Decision standard of chamfering direction of butt joint for sections

Standard of bending radius of plate

Decision standard of bending range for stiffeners

Standard natural twisting angle of rolled and built up section

Standard of no shop bending of rolled and built up section

Decision standard of marking side

TABLE T2-4

GENERAL DEFINITION AND MATERIAL CODING FOR PIPING

Standard of discrimination for piping

Numbering system of piping

Guidance of numbering for pipe fitting

Piping insulation mark

Sub code of piece drawing for pipe

Symbols for piping and ducting

Piping system mark

Material code guidance of common part

Symbols for piping arrangement

Material code guidance of hull piping

TABLE T2-5

DETAILED DESIGN FOR PIPING

Design standard of maintenance space for fittings

Hull outfitting working plan drawing manual

Control piping design manual (Hull part)

Material list for fitting

Application standard of bolts and nuts

Application standard of pipes

Piping diagram

Design standard for pipe penetration pieces

TABLE T2-6

PRODUCTION PRACTICE FOR PIPING

Minimum working space required for welding

Application standard of bender for steel pipes

Application standard of adjusting pipes

Working standard of heat insulation for piping

Standard of bending procedure for pipe

Standard of assembly procedure for butt welded joint

Standard procedure for steel branch pipe assembly

Standard of asssembly procedure for model pipe

Piping practice such as:

- pipe size of piping system
- group of pipes
- fabrication of piping
- bend of piping
- butt welding of steel pipe
- joint fittings
- reducer
- branch
- penetration piece
- surface treatment of pipes
- pipe fitting & accessories

TABLE T2-7

GENERAL DEFINITI0N AND MATERIAL CODING FOR MACHINERY

Standard of abbreviation of machinery

Standard of name for deck flat or floor at E/R

Symbol marks for key plan of hull outfitting

Guidance for piece identification number of fittings

Parts code and piece number for auxiliary machinery seat

Material code guidance of outfitting

Guidance for drawing number of purchase order specification

Material code guidance of machinery part

Term & code number of machinery

TABLE T2-8

DETAILED DESIGN FOR MACHINERY

Design standard of maintenance space for fitting

Hull outfitting working plan drawing manual

Material list for fitting

Application standard of bolts and nuts

Drawing standard for machinery fitting plan

Engine room insulation standard

TABLE T2-9

PRODUCTION PRACTICE FOR MACHINERY

Welding method of fittings

Welding practice of fittings for superstructure

Machining measuring and accuracy of Stern tube

Fitting process of stern bushing

Fitting process for main diesel and shafting

Miscellaneous practice such as:

- tank construction
- ventilating truck
- insulation and lagging
- colour schedule
- foundation of auxiliary machinery
- deck coaming
- fitting method of support

TABLE T2-10

GENERAL DEFINITION AND MATERIAL CODING FOR ELECTRICAL

Marine electrical symbol

Material code guidance of electrical parts

Abbreviated names of electric equipment

Marine electrical system mark

Piece identification number of electric fittings

TABLE T2-11

DETAILED DESIGN FOR ELECTRICAL

Drawing form of electric wiring arrangement

Drawing form of electric fitting arrangement

Installation method of electric cable and appliance

Distance between electric cable way and high fever pipe

Calculation formulary of electric cable ways width

Cable penetration of hull structure

Material list guidance for electric fitting

Shape of electric cable entry to electric equipment

TABLE T2-12

PRODUCTION PRACTICE FOR ELECTRICAL

Installation method of electric cable & appliance

Fitting method of electric cable way & electric apparatus seat to hull structure

Installation method of ceiling light in engine room work space

Standard fitting height of electric equipment

Installation method of bending radial for steel gas-pipe for cable way

TABLE T2-13

GENERAL DEFINITION AND MATERIAL CODING FOR JOINER

Symbol marks for joiner plan

Material code guidance of joiner work

Classification guidance of accommodation fittings

Drawing form of joiner arrangement

Drawing form of joiner work plan

TABLE T2-14

DETAILED DESIGN FOR JOINER

Typical construction of joiner bulkhead at corridor

Typical construction of non-combustible joiner bulkhead at corridor

Typical construction of joiner bulkhead between cabin to cabin

Typical construction of ceiling

Typical detail construction of joiner work

Typical detail construction of non-combustible joiner work

Typical construction of ref. prov. chamber

Drawing standard for working arrangement & fitting plan of accommodation space

TABLE T2-15

PRODUCTION PRACTICE FOR JOINER

Practice of deck covering

Practice of heat insulation in accommnodation

Practice of insulating deck covering

Over the years, the standardization of shipyard data has proceeded hand-in-hand with computerization. The organization of the Aioi design office reflects this relationship by having a Computerization Group comprised of two teams: the Computerization Team and the Standardization Team. As pointed out in the introduction to IHICS (Integrated Hull Information Control System), the need to generate a large volume of detailed information in a short time is a prime goal. The ability to obtain this information with relatively small input is based on a vast amount of previously stored standard data (see Figure 2-3). A detailed explanation of-the IHICS system can be found in the TTP report on Engineering and Design.

2.4 APPLICATION OF IHI TECHNOLOGY

One of the more frustrating developments of the TTP was the realization that there were no great shortcuts-in establishing design standards. There could be very little if any direct transfer of IHI standards to Livingston.

Although there was a tremendous disparity in the number of formal IHI standards to the number of formal Livingston standards, it did not follow that Livingston simply had few standards. Rather a great number of design standards and practices were simply understood as comnon knowledge between engineering section leaders and draftsmen, between engineering sections, and between engineering and production.

Design standards are not separate entities but integral parts of the system. Typical of the problems encountered by Livingston engineers was the comparison of coding conventions for hull items. There are several very

SCOPE OF IHICS SYSTEM

* Covers the detailed design and production engineering for hull.
* Excludes the functions of origination of design concept and structural analysis.
* Maximum output from minimum input.
* Illustration of the proportion of the input required at each stage to the whole information in the system is shown in the following figure.

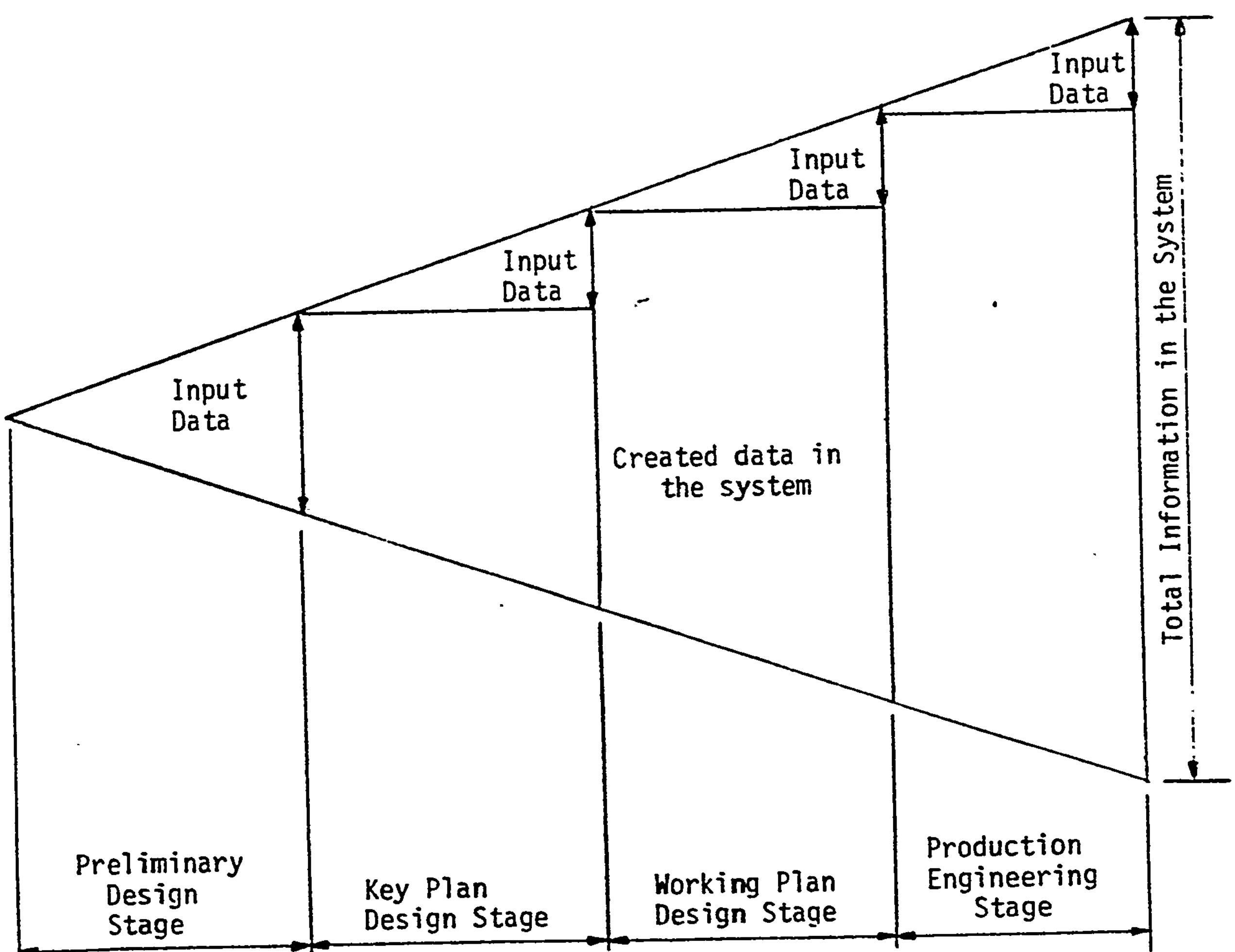

FIGURE 2-3

detailed IHI standards for naming hull blocks (Table T2-1 and Appendix D) but all use an alphanumeric code, while Livingston's code is strictly numerical and ties in with a numerically based work order system.

While direct transfer was not desirable,. the IHI pattern was helpful in form to show to what extent and detail standards and practices should be documented. This pattern of discovery and use was found to be the same for other design sections as well as Hull. Inasmuch as this development occurred early in the TTP, very few IHI standards were actually translated from the Japanese. Effort was directed instead on organizing, developing, and documenting standards.

The greatest difference lay in the area of production-oriented standards formal or otherwise. The design limitations imposed by Livingston facility capabilities or capacities were not well disseminated. The problems that ensued just added to the traditional confrontation between engineering and production groups.

Standards as devices for communication address these problems well. As production facilities become more specialized, the more acute the need for communication (standards). Therefore, when an automated panel line and pipe bending equipment were installed, specific design standards for their use were developed. These and other design standards developed during the TTP are listed in Table T2-16.

Another area took a different route toward standardization. Traditionally, Livingston engineers specified not only the degree of pipe cleaning but the detailed process to be followed. This was divided into two standards. First, a design standard was written setting forth finish and particle size limitations. A second process standard was written detailing the production

TABLE T2-16

LIVINGSTON DESIGN STANDARDS

HULL SECTION

Plan Numbering System
Design Standard for Flat Panels
Hull Structural Standards
Vertical Ladder Standards Details
Inclined Ladder Standards Details
Standard for Lifting Pads

PIPING SECTION

Pipe Bender Guidelines
Grades of Pipe Cleanliness
Pipe Welding Standards
Piping Details

JOINER SECTION

Joiner Standards and Details

MACHINERY SECTION

Standard for Graphic Symbols

ELECTRICAL SECTION

Standards for Graphic Symbols

steps needed to achieve those varying degrees of cleanliness for various types of systems (fuel oil, lube oil, potable water, etc.). This allowed engineering to simply code pipe for various degrees of cleaning without having to write new procedures for each hull.

The effort is continuing to document in the form of standards many existing practices. The departments primarily involved in developing these standards are Engineering, Production and Industrial Engineering.

2.5 CONCLUSION

To meet the goals of building more complex ships and reducing manhour costs, it is essential that efforts within the shipyard become highly coordinated. There is simply no room for wasted or duplicated effort or not efficiently utilizing the extremely expensive production facilities.

To achieve this, there must be:

1) formally written design standards,

2) design and production departments sharing in the responsibility for initiating and reviewing all proposed standards,

3) design and production departments actively work toward achieving a consensus on proposed standards, and

4) a formalized review procedure *must* be established *to revise* or delete existing standards.

SECTION 3

MATERIAL STANDARDS

3.1 INTRODUCTION

One of the most striking aspects of shipbuilding is the large quantity and wide range of materials required. As in many yards, IHI has spread the responsibilities for the material control function among several departments. A vast amount of information is required to be passed among these departments and to vendors. This task is made easier with simple codes tapping detailed descriptions of various materials. Here, as in many other aspects of shipbuilding, IHI has developed standards both as a means of communication and as a basis for a computerized data base.

This section describes how material standards fit into the IHI system. Since they are inextricably interwoven into both the design process and the material control system (purchasing, receiving, storing, and issuing), it is from these two viewpoints that the subject is addressed.

3.2 MATERIAL STANDARDS AND THE DESIGN PROCESS*

For the designer, the material standards perform two functions. First, they tell him what is stocked (or available at short notice) and second, the interfacing requirements for components and equipment,e.g., machinery and foundations, valves and piping, etc. For raw materials, there are corresponding design application standards specifying the range and increment of sizes to be used.

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*See TTP Report Engineering and Design.

Designers specify material in one of three ways:

1) By code referencing a material standard (Standard Drawing) Material requisition classification T.

2) By purchase order specification. Normally, off-the-shelf items in accordance with national standards or vendor-supplied information. Material requisition classification P.

3) By developing Fabrication Drawings for material to be manufactured by subcontractors. Material requisition classification D.

Through the use of handbooks and tables listing the IHI material standards, the designers prepare the various material lists: Material Requisition Orders (for steel), Material List by System (MLS), Material List for Fitting (MLF), Material List for Components (MLC), and Material List for Pipe (MLP). It is by intent that the number of materials specified by Standards (Type T) be much larger than the number specified by purchase order (Type P) or by Fabrication Drawing (Type D). As can be seen in the examples of material lists, Figures 3-1 to 3-4, all of the items are specified by codes which are also directly tied to the numbers for the corresponding standards.

As discussed in the next section, reducing the number of different sizes for either raw materials or components leads to reduced costs for the material control system. This has an adverse effect-on the designer, however, as he no longer has as wide a range of sizes from which to choose. Selecting the next size larger for an item to meet a requirement means over-design or over-specification in many cases. During the Technology Transfer Program, IHI design engineers quite readily accepted this negative impact on design as part of their responsibility to reduce total shipbuilding costs.

MLS 番船別装置部品表

UTIL. CODE	DISCRIPTION	PIECE NO.	CODE	数	NO. (NET) / 数量 (GROSS)	WT (NET) / 重量 (NET)	引出図番	SUB ZONE		備考
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 R/042V	A32	1	10 10	1040 1040		34X171---0 34X171---0	1111X	98 18391 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 R/043V	A32	1	10 10	1040 1040		34X171---0 34X171---0	11117	98 18391 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-025V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-026V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-027V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-028V	A32	1	10 10	1040 1040		34X186---0 34X186---0	11117	98 19177 0800
403002015	** SUB-TOTAL **			100				34		
	** SUB-TOTAL **			100		10400				
403003008	FC S.D.C.GLOBE VALVE FC/BC FN 5050GB	31,30,00 S-222V	A32	1	10 10	148 148		34XH1AP--0 34XH1AP--0	1111A	98 18392 2 0800
403003008	** SUB-TOTAL **			10				34		
	** SUB-TOTAL **			10		148				
403003009	FC S.D.C.GLOBE VALVE FC/BC FN 5065GB 922348 362902	32,60,00 0-019V	A32	1	10 10	213 213		34X118---0 34X118---0	11115	0800
403003009	** SUB-TOTAL **			10				34		
	** SUB-TOTAL **			10		213				
403003010	FC S.D.C.GLOBE VALVE FC/BC FN 5080GB 922367 364901	33,10,00 R-201V	A32	1	10 10	276 276		34XH3AP--0 34XH3AP--0	11115	0800

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MATERIAL LIST BY SYSTEM

FIGURE 3-1

M L F

A : Information for unit assembly
F : Fabrication sign
L : Temporary location sign for next stage
U : unit of quantity
W : Indication of weight

Date
79. 05. 11

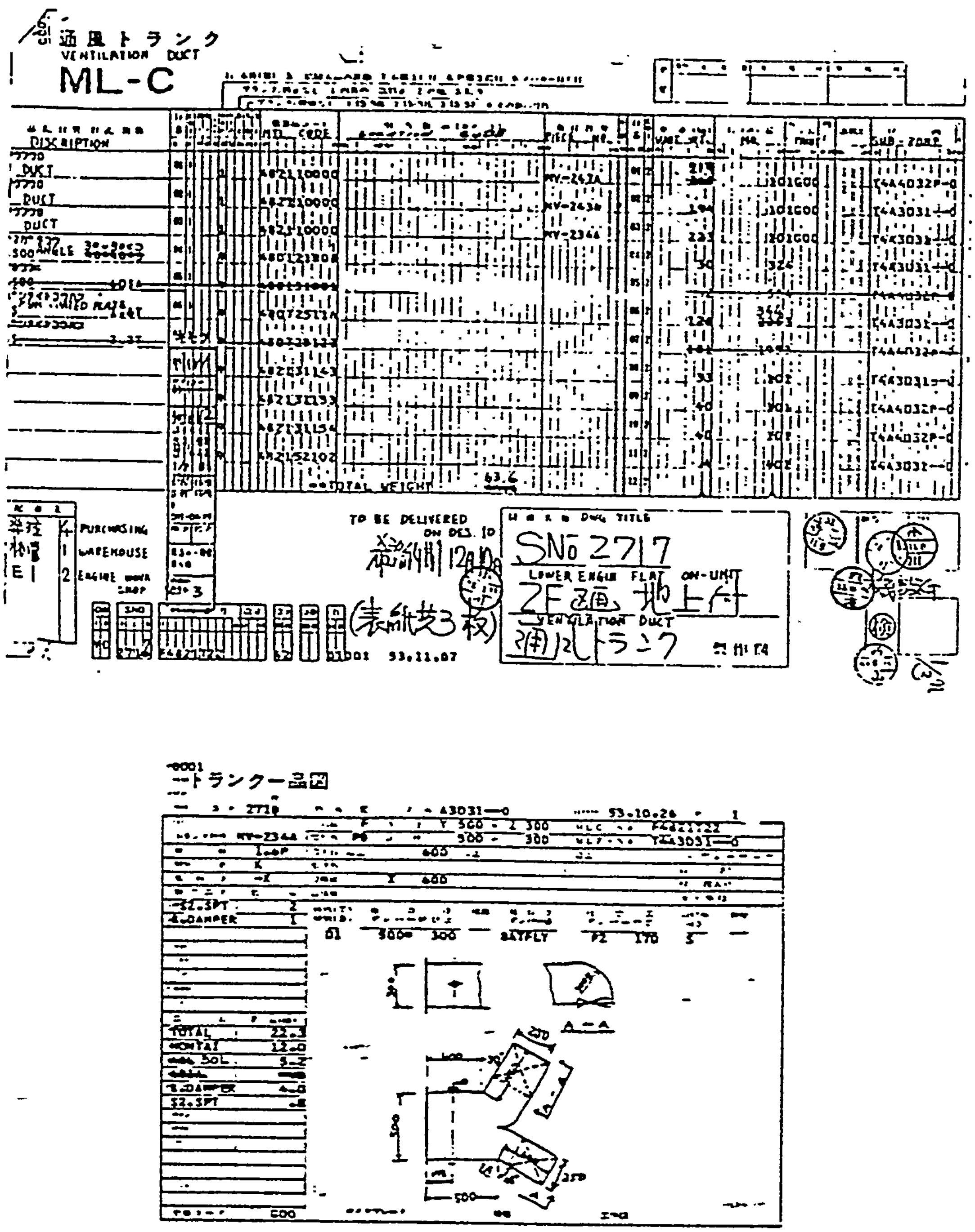
DESCRIPTION	A	Piece No	F	L	Specifications	Qty	U	W	Weight	Paint	Ref Dwg No / MLF No for TLM	Mil code	A	Remarks
BUTTERFLY VALVE(MANUAL)		SW-425V			FC25 SCS13 5K ◆ 200	1U	1	1	240	D44	N4044000	1404496000		◆
BUTTERFLY VALVE(MANUAL)		SW-426V			FC25 SCS13 5K ◆ 200	10	1	1	240	D42	N4044000	1404490000		◆
BUTTERFLY VALVE(MANUAL)		SW-472V			FC25 SCS13 5K ◆ 125	10	1	1	140	D44	N4044000A	1404490000		◆
BLIND FLANGE SS41 GALV.FB 5K 80SSO						1U	1	1	29	R44		4406910130	LA	◆
WATER FILTER		SW-403S			5K-200C (200X250) FIRE GS	1U	1	1	1410	D44	N4082400C	1408250900		◆
WATER FILTER		SW-404S			5K-200C (200X250) FIRE GS	1U	1	1	1410	D44	N4082400C	1408256500		◆
FIRE & G S PUMP		MA-057AA			VEC 180/300M3/H ◆ 80/35M	1U	1		10000		N4451160A	1445116000		◆
FIRE & G S PUMP		MA-057AB			VEC 180/300M3/H ◆ 80/35M	1U	1		10000		N4451160A	1445116000		◆
MOTOR (FIRE & G S P)		P/FGR-M			75KW 1800RPM TE V B	2U	1		13200		N4451170	1445117000		◆
PIPE BAND SUPPORT					N=24	1U	1	1	187		F4634803	2463400000		◆
ORIFICE		SW-401W			10K ◆ 125	1U	1	1	07	D42	N4699300C	1469930000		◆
ORIFICE		SW-402W			10K ◆ 125 (D=39)	1U	1	1	0	NOP	N4699300D	1469930000		◆
VERTICAL LADDER		NG-108V			VFS-5 L/800	1U	1	1	110	D33	F4830212	2483620000		◆
VERTICAL LADDER		NG-101V			VFS-5 L/950	1U	1	1	131	D33	F4830212	2483620000		◆
FLOOR & GRATING		NG-070C				1U	1	1	905		F4831010	2483100000		◆

S. No	MLF - No	Req date	next stage	Work Dwg No	Shop	BClength	Total wt.	Control wt.	Erect wt.	Page
2688	84Y057---0	79 06 01	74BPS31S-0	2U01 .3	7 42 PNO.226		785 / 5171	785 / 5171	785 / 5171	5

(2222)

MATERIAL LIST FOR FITTING (MLF)

FIGURE 3-2



MATERIAL LIST FOR COMPONENTS (MLC)

FIGURE 3-3

MATERIAL LIST FOR PIPE

MLP

DESCRIPTION	S NO	OUTFITTING CODE	C NO	MATERIAL CODE						WEIGHT
15A			94	161001	1			13	0	93.7
25A			94	161003	1			31	0	414.3
40A			94	161005	1			26	0	556.3
50A			94	161006	1			14	0	408.9
65A			94	161007	1			9	0	369.8
15B			94	162001	1			1	0	7.2
25B			94	162003	1			9	0	127.2
40B			94	152005	1			14	0	315.7
65B			94	162007	1			5	0	260.8
25C			94	162103	1			1	0	18.0
40C			94	162105	1			6	0	180.5
50C			94	162106	1			4	0	164.1
65C			94	162107	1			3	0	193.0
25CC			94	162118	1			1	0	18.0
40BB			94	162156	1			2	0	45.1
50BB			94	162157	1			2	0	59.8
65BB			94	162158	1			1	0	50.2
25CC NK			94	172022	1			2	0	35.0
40CC NK			94	172024	1			3	0	90.3
40CC AB			94	178024	1			1	0	30.1
40SC LR			94	184077	1			1	0	30.1
15B AB			94	188004	1			1	0	7.2
25B NK			94	188006	1			2	0	28.3
			94							
			94							
			94							
		TOTAL	94							3,499.6

MATERIAL LIST (MLP)

FIGURE 3-4

3.3 MATERIAL STANDARDS AND THE MATERIAL CONTROL SYSTEM*

The typical IHI material control system is composed of several subsystems:

- -Data entry subsystem
- -Remainder appropriation subsystem (use up leftover materials prior to new purchases)
- -Leveling and balancing subsystem
- -Purchasing subsystem
- -Delivery control subsystem
- -Material receipt and inventory subsystem
- -Material issue subsystem (including palletizing)

When dealing with stock materials, IHI refers to the same set of subsystems as the Inventory Control System. Figures 3-5, 3-6, and 3-7 show the functional flow of the material control system and the purchasing activities.

Along with the material codes and material requisition codes, IHI also classifies material for inventory control purposes. The classifications are:

1) Stocked Materials (S-Material)
   General materials used on various kinds of vessels such as bolts, nuts, joints, packings, small chain, etc. This material is always on hand in a warehouse with set stocking levels periodically adjusted item by item as historical demand indicates.

2) Allocated Material (A-Material)
   Materials used for a specific vessel such as special valves, special pipes, or equipment. The type and quantity is specified item by item by design and purchased in the quantity specified.

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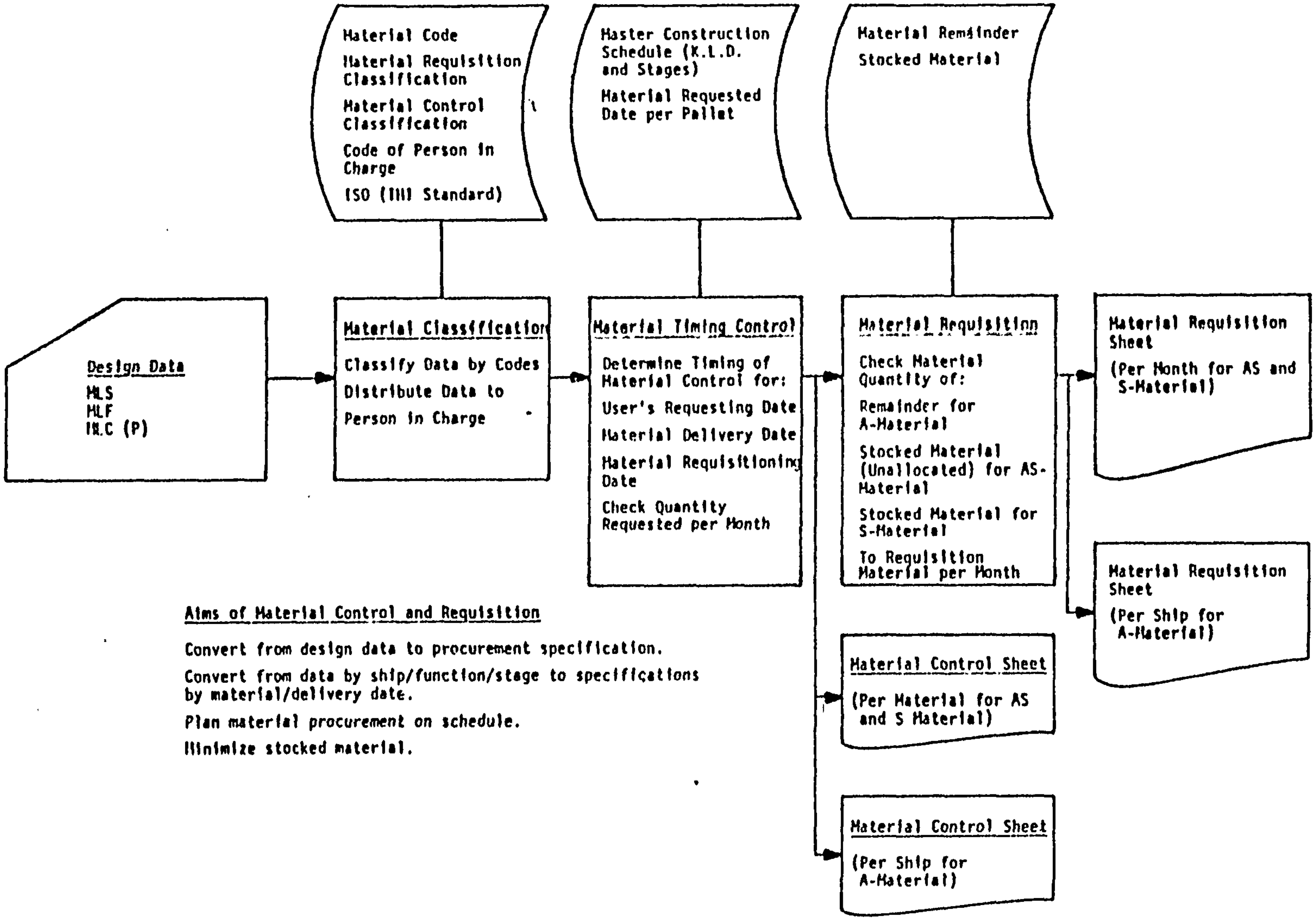
*For details on the scheduling and procurement functions, see the TTP report on Planning & Production Control.



Aims of Material Control and Requisition

Convert from design data to procurement specification.

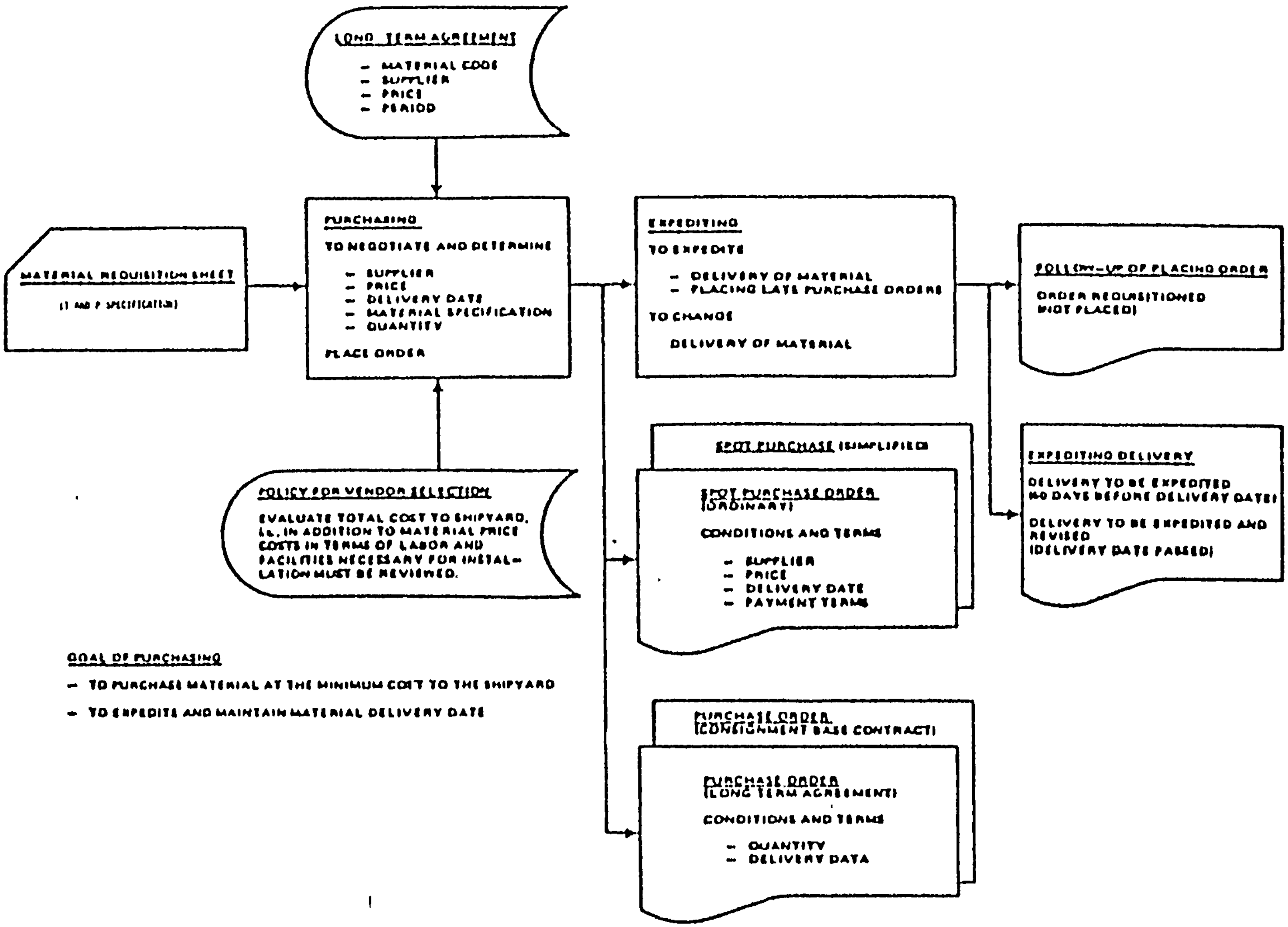
Convert from data by ship/function/stage to specifications by material/delivery date.

Plan material procurement on schedule.

Minimize stocked material.

FUNCTIONAL FLOW OF MATERIAL AND REQUISITION

FIGURE 3-5



PURCHASING PROCESS

FIGURE 3-6

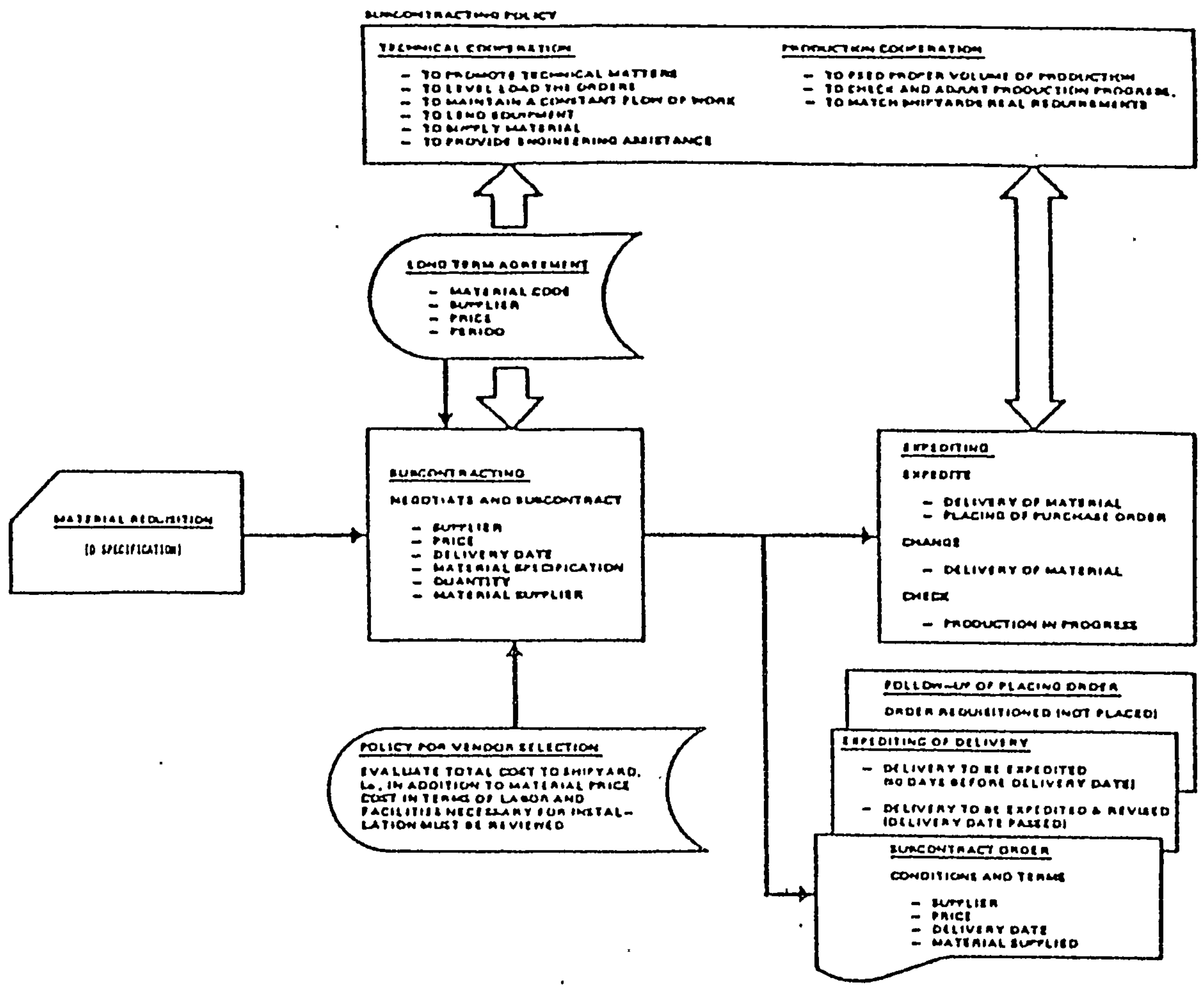


FIGURE 3-7 FUNCTIONAL FLOW OF THE SUBCONTRACTING PROCESS

3) Allocated Stock Material (AS-Material)
Materials used for a specific vessel but needed in large quantities such as pipe, flanges, elbows, etc. The material is ordered in leveled lots with total quantity determined as the design is finalized.

There is a definite relationship between the material requisition codes (T, P, and D) and the material control classes (S, AS, and A). Materials specified by standards (T) fall into all three of the control classes while those specified by the other two methods (p and D) are designated as Allocated Stock (AS) materials. Table T3-1 lists the Allocated Stock Materials for the Future 32 ship used as a basis for the Technology Transfer Program.

Another way of saying the same thing is that IHI has developed standards or uses the national standards for most of the materials used in shipbuilding. Much of the material is purchased under long term contracts by the Tokyo Head Office or through constant single sources and families of subcontractors virtually slaved to the shipyards. With the standards forming the data base for the IHI computer-oriented material control system such vendor relationships have lead to greatly reduced purchasing costs. These cost savings come about through reduced purchasing manhours, quantity discounts and reduced inventory due to reduced uncertainty in delivery times.

IHI has made consistent and concerted efforts to reduce the amount of material in inventory whether it be in the warehouse, steel stock yard or in-process. Largely as a result of better scheduling (see *Section* 6- Cost Standards) both in-house and with vendors, these efforts have succeeded. An extreme example perhaps is that the steel stockyard at the Aioi shipyard maintains only a three to four day supply of steel. Along with

TABLE T3-1

LIST OF STOCKED OR ALLOCATED STOCK MATERIALS FOR BULKER

NAME OF MATERIAL

HANDLE (GRIP TYPE)
STEP (ROUND BAR)
SHIP'S EYE PLATE (C-TYPE)
DITTO (D-TYPE)
CARBON STEEL PIPE FOR ORD. PIPING
WELDED STEEL PIPES
CARBON STEEL PIPE FOR PRESS. SERV.
DITTO HIGH TEMP. SERV.
COPPER PIPE AND TUBE
RIGID POLYVINYL CHLORIDE PIPE
MARINE CAST IRON 5 K/CM^2 GLOBE VALVE
DITTO ANGLE VALVE
DITTO 10 K/CM^2 GLOBE VALVE
DITTO ANGLE VALVE
DITTO 5 K/CM^2 GLOBE UNION
BONNET TYPE
MARINE CAST IRON 5 K/CM^2 ANGLE UNION
BONNET TYPE
MARINE BRONZE 16 K/CM^2 GLOBE VALVE
DITTO ANGLE VALVE
DITTO 20 K/CM^2 BITE TYPE GLOVE VALVE
MARINE BRONZE 20 K/CM^2 GLOVE VALVE WITH BITE UNION
5 K/CM^2 SLIP-ON WELDING STEEL FLANGE
10 K/CM^2 DITTO
16 K/CM^2 DITTO
5 K/CM^2 BRASS FLANGE FOR COPPER PIPE
10 K/CM^2 DITTO
5 K/CM^2 FLANGE FOR POLYVINYL CHLO. PIPE
DITTO BLIND FLANGE
10 K/CM^2 DITTO
PIPE BLIND PLATE
SLEEVE TYPE PENETRATING PIECE
STEEL PIPE 90° SHORT ELBOW (FSGP)
DITTO (SS41)
DITTO (PT38, SCH40)
DITTO (PT38, SCH80)
STEEL PIPE (SGP) CONCENTRIC REDUCER
DITTO (PT38) DITTO (SCH40)
DITTO (SCH80)
SLEEVE TYPE JOINT FOR STEEL PIPE
SOCKET BRAZED SLEEVE JOINT
70 K/CM^2 BOTH SIDE UNION FOR COPPER PIPE
70 K/CM^2 TEE WITH BITE FOR COPPER BITE
90° ELBOW FOR RIGID POLY. CHLO. PIPE
45° DITTO
REDUCING TEE FOR DITTO
90° REDUCING "Y" PIECE FOR DITTO
THREADED OUTLET
STEEL (SS) DRESSER TYPE COUPLING
SCUPPER FOR STEEL DECK (5 K/CM^2 TYPE)
DRAIN PLUG FOR STEEL WALL
PRESSURE GAUGE BOARD
STANCHION FOR GRATING
SWITCH TYPE FIT2
SWITCH TYPE 2
RECEPTACLE WITH SWITCH TYPE S1
JOINT BOX (W.T.) TYPE 1 & 2
OUTLET BOX TYPE C
BANDING TYPE CABLE HANGER
CABLE RACK TYPE SS
CABLE RACK TYPE RS1
CABLE SADDLE TYPE SF
ELECTRIC CABLE SADDLE TYPE UL
CABLE MOLE (POLYVINYL)
ELECTRIC CABLE TRAY TYPE CT
CABLE COAMING TYPE CA
CABLE COAMING TYPE CE
MARINE WATERTIGHT CABLE GLANDS TYPE G
ELECTRIC CABLE CONDUIT TYPE E
FITTING LEG TYPE PL1 FOR PENDANT LIGHT
FITTING LEG TYPE PL5 FOR HANGING TYPE PENDANT LIGHT
FITTING LEG TYPE PL7 FOR HANGING TYPE PENDANT LIGHT
SEAT FOR BULKHEAD LIGHT TYPE WL3
SEAT FOR SWITCH, RECEP., ETC. TYPE ST
SEAT FOR JOINT BOX TYPE SJ-2
SEAT FOR OUTLET BOX TYPE OT-A
SEAT FOR WIRING APPARATUS TYPE SOT-C
WIRE ROPE

frequent deliveries of steel from the mill nearby, Livingston observers noticed a long line of vendors' trucks lined up every morning at the main gate.

Warehousing is needed to act as a buffer between two rates i.e., the vendor delivery rate (including purchasing lead time) and the production side consumption rate. The size of that buffer depends on two things: 1) the disparity or uncertainty in the input/output rates and 2) the number of different items that require identifying, marking and segregation. Cost standards, as noted above, address the production consumption rate. Material standards address both points.

Many major U. S. yards have realized reductions in inventory carrying costs (as wel1 as the acreage) by standardizing the numbers of different sizes and thicknesses of steel plates. IHI has carried this process to other materials which in itself was a major driving force in the establishment of material standards.

3.4 LIVINGSTON APPLICATION

Before this program, the number of IHI material standards greatly exceeded the number of Livingston material standards and it still is the case. From many different quarters within Livingston, the list of insurmountable obstacles to increased standardization was heard loud and long: differences in government regulations, shipyard-vendor relationships, cultural differences, competing sources of U. S. standards, the purchasing power Japanese shipyards have with multi-ship contracts, and so on. Many of these are valid and will hinder the development of material standards for some time to come. "

As a result of the study, Livingston developed its own version of a standard for sizes of steel plates and has started to revise its material stock catalog. The overriding benefit of the program, however, is the awareness at many levels within the company of the importance of material standards for effective communication and inventory reduction and a commitment by management to continue to develop those standards.

TOLERANCE STANDARDS

4.1 INTRODUCTION

In order to understand the importance and the development of tolerance standards at IHI, the Accuracy Control concept must first be explained. Accuracy Control is an integral part of the Quality Control function at IHI. The concept of Accuracy Control is simple in definition but complex in application. A full discussion of the Accuracy Control system is provided in the TTP Final Reports entitled:

Quality Assurance - Volume 1 Report

Quality Assurance - Volume 2 Appendices

The Concept and Application of Accuracy Control

Special Report: Accuracy Control Planning for Hull Construction

In these reports, the objectives of Accuracy Control were stated as being:

1) To maintain the highest accuracy possible at each stage of production of every fabricated piece, part, sub-assembly, assembly and erected unit.

2) To minimize the work at the erection stage.

3) To consistently improve the production stage to yield the highest accuracy in all products.

At IHI, Accuracy Control is a system inherent in the design and production process beginning in Engineering and proceeding through mold lofting, marking, cutting, bending, welding, sub-assembly, assembly, erection and in outfitting activities.

The main goal of Accuracy Control is to perfect each production method, technique and process to such a degree that each worker activity has definitive standards to be achieved, a prescribed method of measurement for finished material, and a continuous flow of information between activities resulting in the constant improvement of product quality and production efficiency.

The basic operating premise of Accuracy Control is to keep high accuracy in the shape of the major hull units at the erection stage. The objective of this accuracy is to minimize the number of labor hours and the difficulty of the work during erection. This is accomplished through a sophisticated system of standards, “check sheets”, inspections and measurements during each phase of ship construction. The concept of Accuracy Control at IHI, indicating the objectives of the system, the location of the planning function by the A/C group, and the point of application of dimension checks and allowable tolerances, is provided as Figure 4-1.

The Accuracy Control function comprises three elements: Planning; Field Activity; and Data Analysis and Information Feedback. Each of these activities is carried out by several different groups located in different departments: the Shipyard Design Department, the Panel Workshop, the Hull Workshop and the Fitting Workshop. These Accuracy Control groups report to the managers or superintendents of their respective departments or workshops.

The activities of these various groups are started well in advance of the development of working drawings. Accuracy Control Planning is undertaken on the basis of preliminary (basic) design (which is generated by the IHI Head Office in Tokyo) several months prior to the start of fabrication. This planning effort involves participation with the

CONCEPT OF ACCURACY CONTROL AT IHI

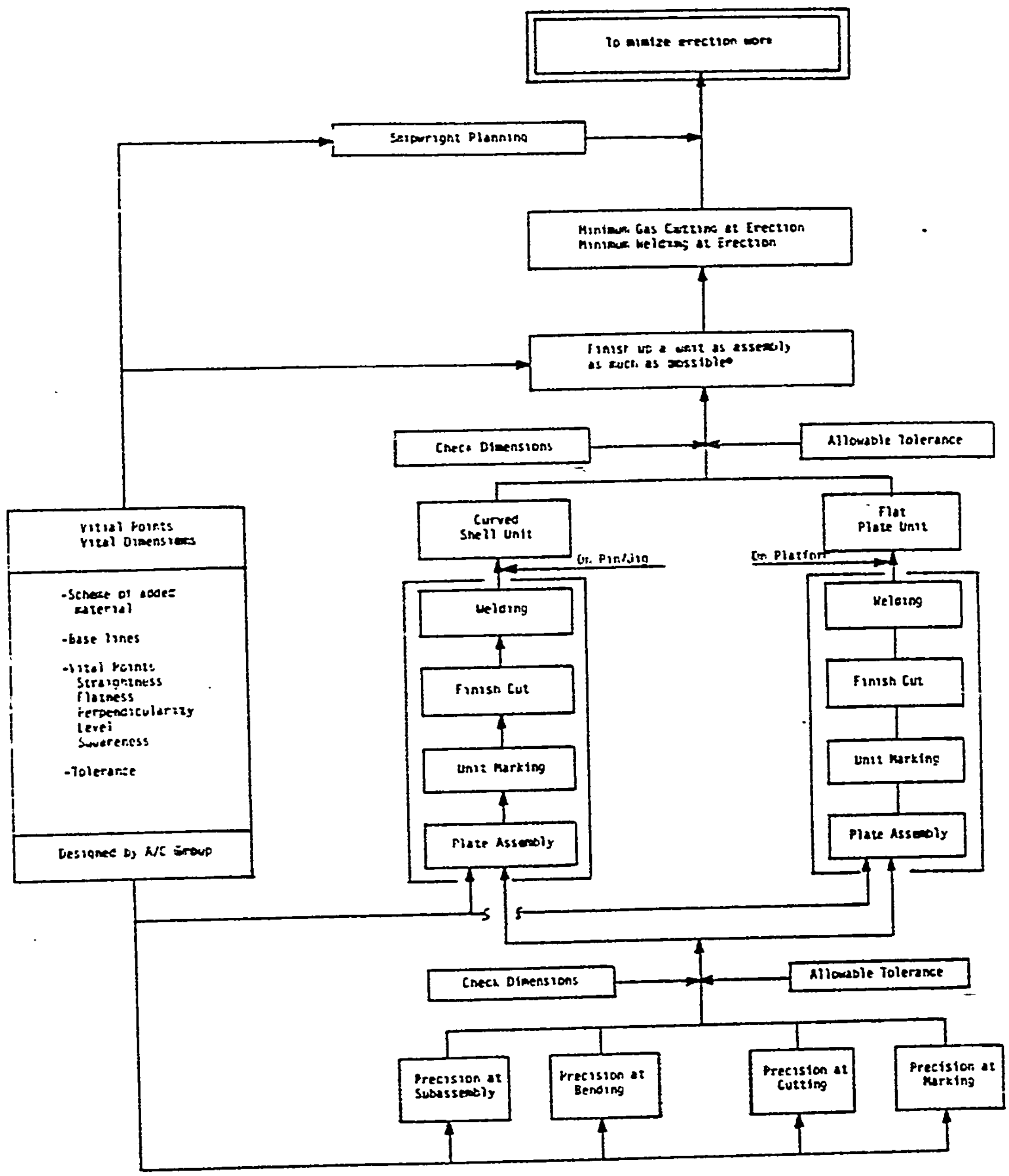


FIGURE 4-1

designers in determining the ship breakdown, the fabrication sequence, the assembly sequence, and the erection sequence. Subsequently, Accuracy Control Planners develop: Vital Dimensions and Points of Accuracy; the Scheme of Added Materials; Base Lines for lofting and measuring; and Tolerance Standards for the ship being planned.

Subsequent to the completion of the Accuracy Control Planning and to the start of fabrication, Accuracy Control Field Activities begin. These activities consist of development of: check sheets for fabricated pieces, sub-assemblies, assemblies, and erected units; template and plate layout requirements; methods for cutting and measurement of plates; and fabrication methods. Actual fi_eld measurements are then taken on the manufactured pieces and assemblies by workers, Accuracy Contol personnel and Quality Control personnel in accordance with the check sheet requirements. Through this process, data are collected for subsequent analysis and information feedback to design or production groups.

4.2 TYPES OF TOLERANCE STANDARDS AT IHI

In all IHI shipyards, the use of tolerance standards is an integral part of the design and production process. Tolerance standards have evolved from actual production practices over many years and many a series-run of ships. For many ship types, standard tolerances are firmly establ"ished and require little, if any, modification. In these cases, Accuraccy Control Engineers simply review ship specifications for any requirements that would cause a change to those already in practice. In the case of a new ship type, standard tolerances are reviewed and changes effected where necessary to comply with specification requirements or with differing technical requirements for that ship. Generally, no major revision of tolerance standards is required even on new ship types.

The Aioi Shipyard has developed the Accuracy Control organization over several years. The two methods undertaken at IHI-Aioi, illustrated in Figure 4-2, are:

REGULAR CONTROL	SPECIAL CONTROL
1. Accuracy setting of equipment i.e., N/C burning machine Flame planer - Welding machines	1. Specific tolerance requirements for a ship type
2. Standards for typical hull parts & pieces	2. Specific requirements to preserve accuracy of vital points

FIGURE 4-2

The “regular control” type is concerned with the routine tolerance accuracy of fabricated pieces of any ship and with the accuracy maintenance of the machines which process those pieces. Accuracy Control Engineers are responsible for field checks of both the fabricated pieces and of the related machines such as the N/C burning machine, the flame planer and all welding machines. Results of these field checks are analyzed and plotted on time-based control charts to detect any increase in out-of-tolerance performance.

Tolerance may be modified as a result of the Accuracy Control planning for vital dimensions and points of accuracy on individual components or assemblies. The data collected by Accuracy Control groups at the time of measurement of sub-assemblies or assemblies may indicate a change to a certain tolerance at some particular stage of processing. The data analyzed may, for example, show a trend toward an out-of-tolerance condition through the accumulation of marginal tolerances in several pieces combined into one sub-assembly. In this case, certain tolerances would be adjusted to assure that the accuracy of the sub-assembly was preserved. This type of tolerance control is called “special control” and is primarily oriented toward improvement of tolerance standards for a particular ship type.

4.3 DEVELOPMENT OF TOLERANCE STANDARDS

During initial production, Accuracy Control-planning is put into use. Accuracy Control activity in production begins in the area of mold lofting where vital points and dimensions are specified for templates and plate layouts. Methods to be used for burning and measurements of cut plates are also specified. The fabrication sequence is implemented through detailed schedules prepared for every level of work and measurement requirements are instituted by means of Accuracy Control Check Sheets. During the Production Planning phase, the Accuracy Control groups “prepare a Check Sheet for each unit of the ship. This Check Sheet defines the points to be measured, the checking method, personnel responsible for the checking, and the frequency of measurement required. Examples of these check sheets for Fabrication, Assembly and Erection stages are provided as Figures 4-3, 4-4 and 4-5.

Using these Check Sheets, measurement of fabricated steel and units is performed using instruments such as scales,-wire, transits, plummets and special jigs used for unique parts not amenable to measurement by ordinary techniques.

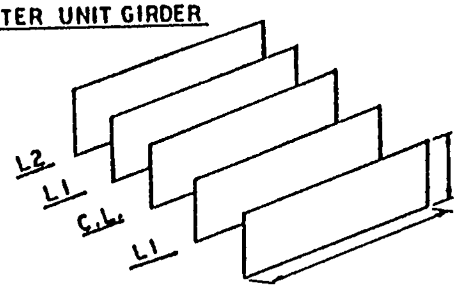
IHI uses these check sheets to develop a history of recorded data on checks of fabricated, assembled and erected pieces. With a log containing over fifteen years’ collection of.data, IHI was able to develop standard and tolerance tables for each of these processes on all units. The values of these tolerances are generally stricter than those established by the ship’s owners and the Japanese classification societies. The JSQS (Japanese Shipbuilding Quality Standards) is the main source for Japanese shipbuilding standards.

ACCURACY CONTROL CHECK SHEETS - FABRICATION

ACCURACY CHECK SHEET

SHIP NO	UNIT NO	SHOP	CONDITION
		Cut Sub-Assy.	All Pieces

BOTTOM CENTER UNIT GIRDER

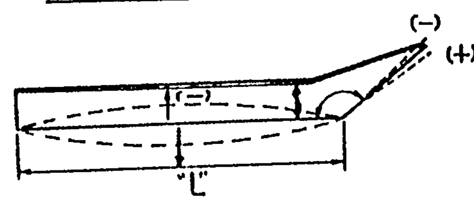


Ship No.	Piece Name	Length	Height	Unit No.	Piece Name	Length	Weight

ACCURACY CHECK SHEET

SHIP NO	UNIT NO	SHOP	CONDITION
		Sub-Assy.	All Pieces

HOLD FRAME



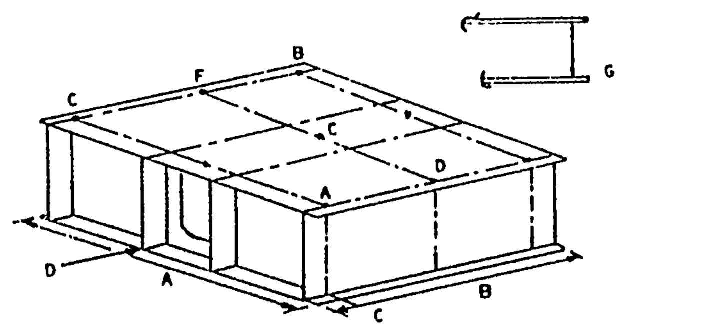
PIECE NAME	LENGTH (L)	DEFORMATION	ANGLE

FIGURE 4-3

ACCURACY CONTROL CHECK SHEETS - ASSEMBLY

ACCURACY CHECK SHEET

SHIP NO	UNIT NO	SHOP	CONDITION
			FINAL UNIT ASSEMBLY

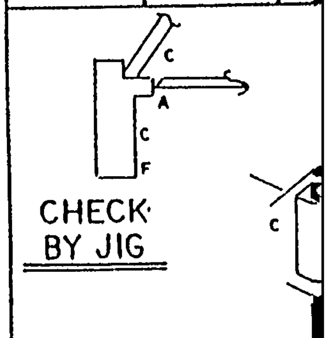


MARK	ITEM	DRAW DIM.	ALLOW TOL.	ACTUAL DIM	CHG.	NOTICE
C			P S			
D			F A			
E			P S			
F						
G						
H						

NOTICE: AFTER FITTING,WELDING

ACCURAC

SHIP NO	UNIT NO	S



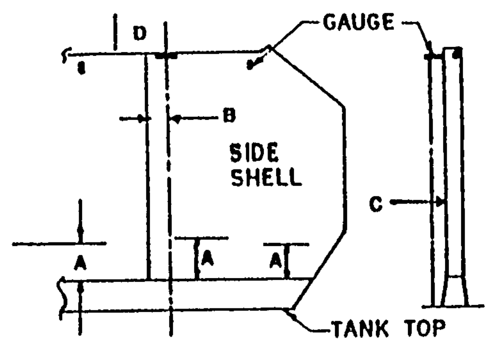
MARK	ITEM	DRAW DIM.	A
A	BUTT ALIGN.		
B			
C			

NOTICE: 1 AFTER FITTIN
2 TOP SEAM AT

FIGURE 4-4

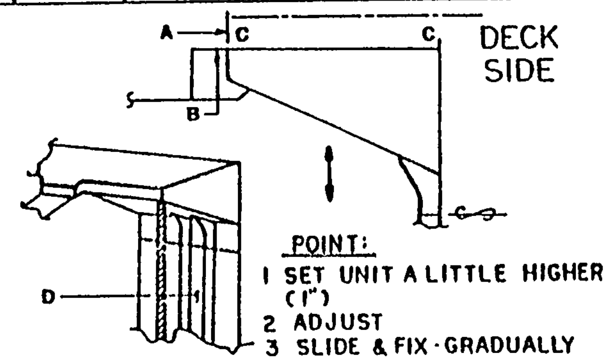
ACCURACY CONTROL CHECK SHEETS - ERECTION

HULL NO	UNIT	ERECTION SEQ.	WT. (T)	SHIPWRIGHT
				CORR BHD



MARK	DESCR.	DIMEN.	TOLR.	CHG.	NOTICE
A	HEIGHT			WKR.	CHECK AT MARKED LINE IN FINAL ASSEMBLY
B	CENTER-LINE				
C	PERPENDICULAR CHECK				
D	WIDTH				

HULL NO	UNIT	ERECTION SEQ.	WT.(T)	SHIPWRIGHT
				UPPER WING



MARK	DESCR.	DIMEN.	TOLR.	CHG.	NOTICE
A	WIDTH			WKR. A.C.	MEASURE FROM CENTER LINE BY RULER
B	HEIGHT				
C	LEVEL				
D	ALIGNMENT AT EACH FRAME				

Inserted Unit: Before inserting, the length between units (inserted space) should be checked and finish cut. Inserted unit should be neat cut at final assembly.

FIGURE 4-5

4.4 EXAMPLES OF TOLERANCE STANDARDS

Examples of tolerance standards for the two types of control, regular and special control, are provided as Figures 4-6 and 4-7. A complete text of tolerances in use at IHI is provided in the TTP Final Report on Quality Assurance, Volume 2, Appendices F, G and H, entitled as follows:

Appendix F: IHI SPAIS - The Shipbuilding Process and Inspection Standard

Appendix G: Standard and Tolerance for Keeping High Accuracy at IHI - Aioi Shipyard

Appendix H: Schedule and Particulars of Inspection and Testing (Bulk Carrier)

Accuracy Control Check Sheets are used by workers, group checkers, assistant foremen, and Ouality Control Inspectors as the guiding information in the fabrication and assembly of all parts of the ship. Use of the Accuracy Control Check Sheets and the IHI Standards manual provide complete information as to the dimensions, methods and other requirements expected from the production process. Nothing is left to guesswork on the part of workers or their supervisors.

SHOP	ITEMS TO BE CHECKED	ALLOWABLE TOLERANCE	FREQUENCY OF MEASURING
Marking & Gas Cutting			
(Section)	*Line for gas cutting of angles (after cutting)	e = ± 1/32"	5 pc/day
	*Length of angles (after cutting)	e = ± 1.5/64"	5 pc/day
(Internal Member)	*Normality after gas cutting (right angle)	e = ± 2mm per 1500mm	5 pc/day
	*Line for gas cutting	e = ± 1/32"	"
	*Length after gas cutting	e = ± 3/64"	"
	*Width after gas cutting	e = ± 3/64"	"
<u>Flame Planer</u>	*Length & Width after cutting	e = ± 1.5/64"	5 pc/day
(Flat Shell Plate Flat Plate	*Straightness	e = ± 1/64"	2 pc/week
	*Bevel Angle	e = ± 2.0 deg.	5 pc/day
	*Normality (Right Angle)	e = ± 2mm per 1500mm	2 pc/week

FIGURE 4-6

TOLERANCE STANDARDS REGULAR CONTROL (EXAMPLES)

SHOP	ITEM	TOLERANCE	FREQUENCY 01. MEASURING	REMARKS
<u>ERECTION</u> Bottom Shell	*Positioning (Length wise) Measure on the check points on berth	$e = \pm 1/8"$	Starting unit only	
	*Positioning (Height) Measure at the most forward frame (2 points)	$e = \pm 1/4"$	All Units	By Gauge
	*Level: (Between left side and right side) Measure on the points at forward edge	$e = \pm 1/4"$	All Units	Pay attention to twist
	*Positioning: (Between left side and right side) Measure at the forword butt	$e = \pm 1/8"$	All Units	Plumb down to the base line on berth
	*Connecting part between units: Check the bevels at seams and butts	$e = \pm 1/8"$	All Units	
	*Discrepancy of ship's center	$e = \pm 1/8"$	All Units	Measuring by transit

FIGURE 4-7
TOLERANCE STANDARDS SPECIAL CONTROL (EXAMPLES)

4.5 FEEDBACK SYSTEM AND STATISTICAL ANALYSIS

The Accuracy Control Group at IHI uses a feedback of actual data-collection records and applies statistical analysis techniques to these . data to develop their tolerance standards. The flow of this feedback is illustrated in Figure 4-8.

Each piece and part is measured at successive stages of its progression through the production process. The measurement of these pieces determines whether or not the piece is within the specified tolerance. The Japanese are acutely aware of the effects of cumulative errors or marginally acceptable materials as they progress through the building process. They recognize the importance of identifying and correcting persistent marginal errors and even the tendency toward persistent errors in specific production areas or processes. As a result, they have adopted a statistical analysis method to examine and reduce errors that recur .persistently throughout the building of a specific ship type. This statistical analysis method is based on the data accumulated through the use of a Quality Control Check Sheet, shown as Figure 4-9. This check sheet is used for each unit at each production stage and is signed by the assistant foreman, the group checker and finally by the Quality Control inspector on a number of various conditions which may exist on the work at each work station. One side of the check sheet is used for “Welding” inspections while the reverse side is used for “Accuracy” inspections, (WQC indicates Welding Quality Control -AQC refers to Accuracy Quality Control). This Check Sheet is physically attached to the component or unit undergoing fabrication or assembly and is used throughout the inspection process to document deficiencies and corrective action. All deficiencies are corrected by

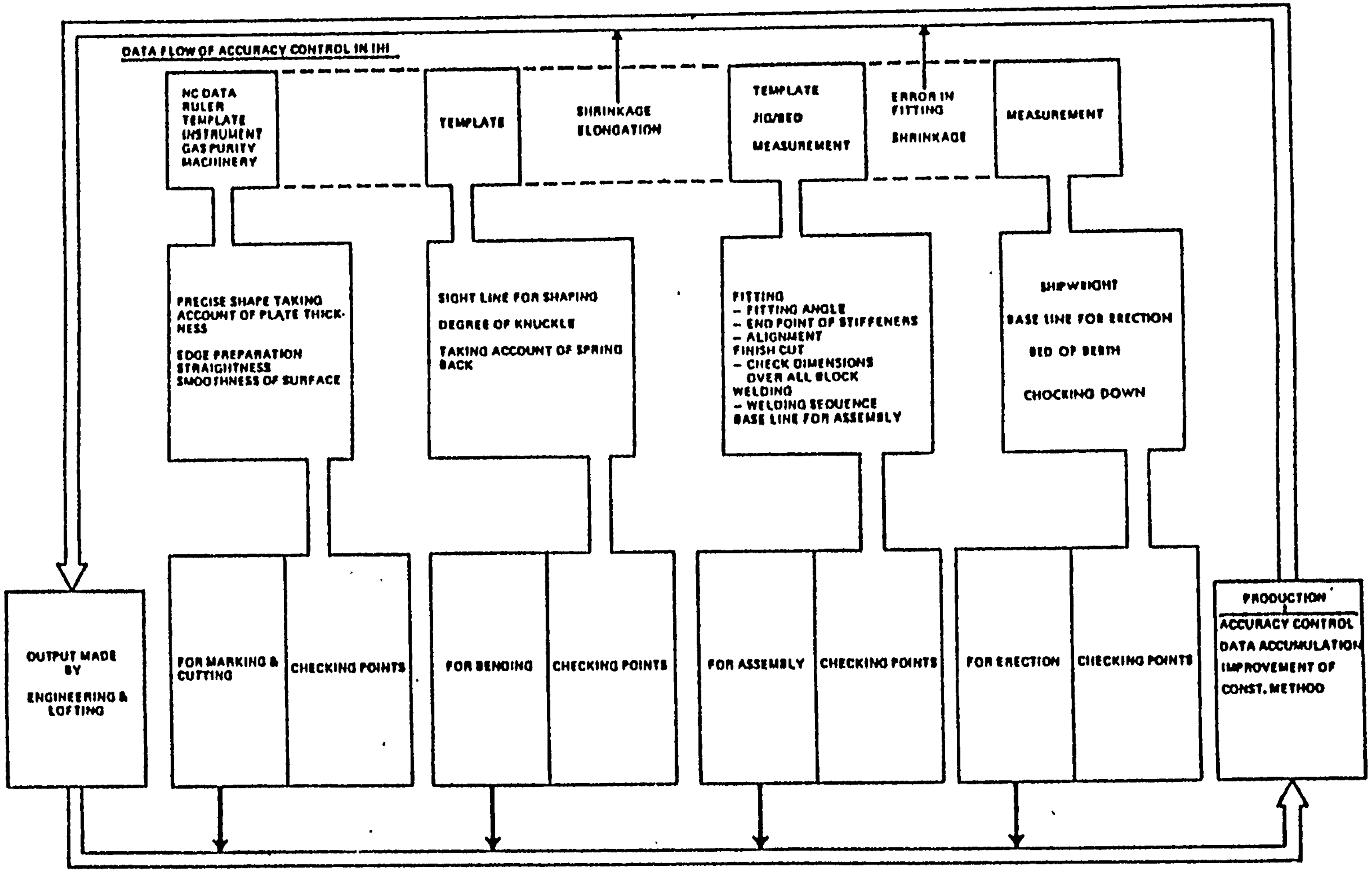


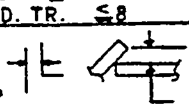
FIGURE 4-8

DATA FLOW OF ACCURACY AT IHI

A.Q.C. CHECK SHEET

	SUB-ASSEMBLY
	ASSEMBLY
	ERECTION

S. NO		BLOCK OR TANK		BLOCK-WT.	TONS	SHOP	

GRADE	CHECK POINT \ CHECKER			LEADER QC 1	REP.	Q.C.MBR. QC 2	REP.	INSPECTOR	DE-MERITS		REP.
A	MISFITTING								11X 4X		
	SCANTLING CHECK								11X 4X-2X		
B	MISALIGNMENT										
		MAIN STR	OTHERS								
	BUTT	<1.5T	<0.2T						4X		
		MAX. 3									
	FILLET	<T/3	<T/2						4X		
	GAP										
	BUTT	5	G≦5						4X		
		T/2	<G≦T/2								
	FILLET	3<G<5							4X		
		5<G<T									
	DEFORMATION TANK F&A IN SHELL ≦6 ≦7 DECK ≦6 ≦8 TANK TOP ≦8								4X		
	BHD ≦8 GIRD. TR. ≦8								4X		
C	GAP LAP 								4X		
	DEFORMATION IN. FL. & G IN. DR. ≦8								2X		
	STIFF. & BEAM HOUSE WALL ≦8								2X		
D	NOTCH EDGE ROUGHNESS								2X		
	OTHER MINOR ITEMS 5 DEFECTS : 1 POINT								TOTAL		

SUMMARY	LEADER	A	B	C	D	QC MEMBER	A	B	C	D	INSPECTOR	A	B	C	D
	—DO—					—DO—					—DO—				

REMARKS					
	LEADER				
	INSPECTOR				
	CLASS				

FIGURE 4-9

the worker making the error even if the work has been moved to another work station. The sheet is also used by assistant foremen to remedy continuing problems in cutting, fitting or welding by identifying persistent problems and either obtaining a correction in design or educating workers in proper techniques to prevent a recurrence.

During the processing of steel, each welder identifies his work by signing each weld he has made. By this means the group leader .and checker/ inspectors can identify the individual responsible for the work. In outfitting, work is identified to a specific work group by reference to schedules and work locations. This is done in each stage of production. A weighted factor (based on the importance of the work-performed) is applied by the inspector to each error to achieve a summary “grade” or “bad mark” for each item inspected. The purpose of this system is related only to each individual’s pride in his workmanship. No disciplinary action is taken as a result of “bad marks”, it is simply a means of publicizing superior or-poor work both to the individual worker and to his work group. These records are also used to assess the performance of each group. Throughout the shipyard, quality control statistics for work groups and production units are posted to continually reinforce quality awareness.

A typical-record sheet showing measurements taken by the workers at the butt welding station on the panel line is shown on Figure 4-10. These records are maintained by the Assistant Foreman of the shop, and are analyzed by the field engineers, after compiling these data.

An example of an Accuracy Control chart prepared to show the accuracy of gaps for butt welding is given as Figure 4-11. This type of chart is

BUTT WELDING RECORD SHEET

HULL 752

UNIT 132

	I.D. NO.	THICKNESS
PLATE	#1	½"
PLATE	#2	½"
PLATE	#3	½"

PL #1

6^{mm}	5^{mm}	4^{mm}	3^{mm}	4^{mm}	4^{mm}	5^{mm}	6^{mm}

Pin Holes   Overlap   Undercut

PL #2

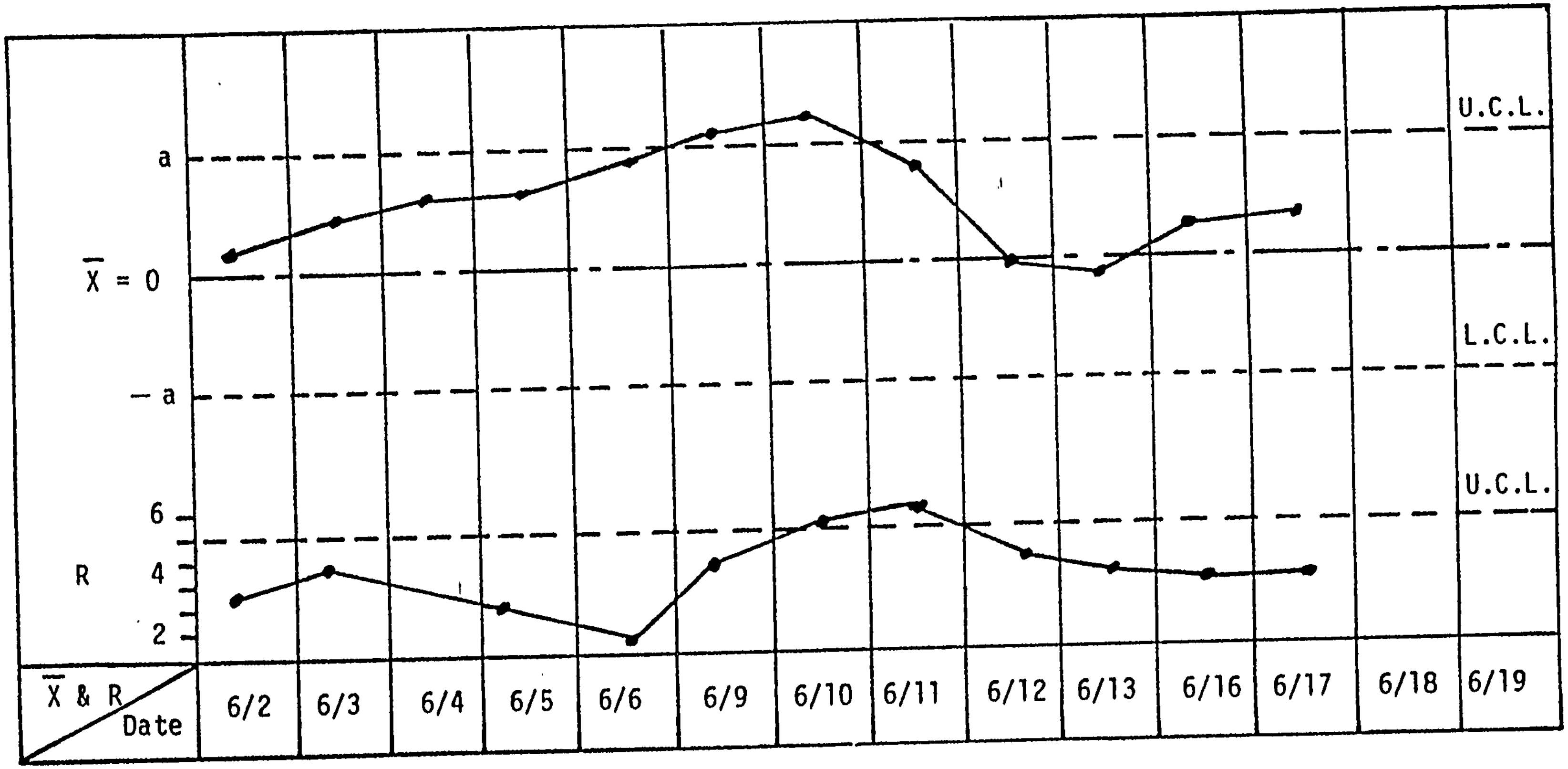
8^{mm}	5^{mm}	3^{mm}	3^{mm}	4^{mm}	4^{mm}	4^{mm}	5^{mm}

Pin Holes   Pin Holes

PL #3

CONDITION OF STEEL	GOOD	AMPS	230 a
NEATNESS OF BEVEL	GOOD	VOLTS	600 v
HUMIDITY	OK	SPEED	600 $^{mm}/_{min.}$

FIGURE 4-10



<u>$\bar{X}$-R Chart Examples:</u>

Edge Adjustment
Gap
Degre of Slant

FIGURE 4-11

ACCURACY CONTROL CHART

developed using the type of data compiled on the Butt Welding Record Sheet and applying customary statistical analysis techniques.

The control chart consists of a central line corresponding to the average quality at which the process is to perform and lines corresponding to the upper and lower control limits. These limits are determined so that the values falling between them are representative of an acceptable process control, while values falling beyond them are interpreted as indicating a lack of control. The ability to read control charts and to determine from them just what corrective action should be taken is a matter of experience and highly developed judgment. The IHI A/C Engineer is trained in this technique and becomes skilled in its application and interpretation. The charts provide a means of translating technical information into a form understood by workers at all levels.

The symbols shown on this Accuracy Control chart are defined as follows:

For $\overline{X}$ Curve:

$$L.C.L. = \overline{X} - A_2 \overline{R}$$
$$U.C.L. = \overline{X} + A_2 \overline{R}$$

For R Curve:

$$L.C.L. = D_3 \overline{R}$$
$$U.C.L. = D_4 \overline{R}$$

$$\overline{X} = \frac{\text{Sum }(X)}{N}$$

$$R = Xmax - Xmin$$

$$\overline{R} = \frac{\text{Sum }(R)}{N}$$

Where:

Y = Mean (Average) Value of measured data (or error)
A2 = Constant
N Number of samples taken
Xmax = Maximum Sample Error Taken
Xmin = Minimum Sample Error Taken
R = Range of Values (highest to lowest)
D3 & D4= Constants

In this type of analysis, random sampling techniques may be used to gather data. In such a case, the sample values must be obtained in random fashion to make the analysis valid. The data used as sample values may be actually measured dimensions or the amount of error in each measurement, in which case the mean value of X is zero.

Data gathered in this feedback process is analyzed to determine the possible causes and implications of the error on “downstream” work. The Accuracy Control Engineer analyzing the error may take one of several alternative corrective measures, such as:

- Continue a more detailed investigation
- Review the fabrication method (to prevent heat distortion, to improve the sequence of activity, etc.)
- Investigate the measurement instruments and methods
- Investigate the foundation (such as the platform as. assembly or cribbing at erection)
- Investigate the adequacy of the added material

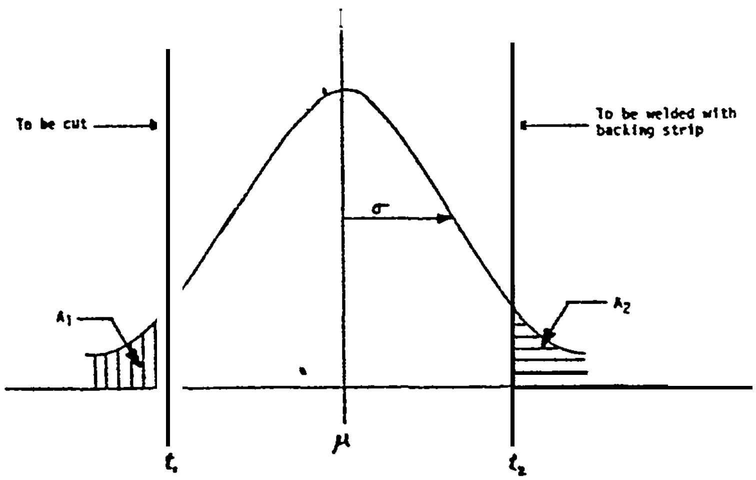
Based on the statistical findings, the engineer deduce that the fabrication method itself yields a large variance and may result in out-of-tolerance errors. In this case, he will take steps to perfect the fabrication method to obtain uniform and acceptable results on each piece so fabricated. This may involve a change in fabrication sequence, methods, personnel training or adoption of an entirely new fabrication process.

An example of corrective action taken on the basis of analysis of statistical data follows:

The following conditions may exist when the gap is measured, for which appropriate action for each condition is specified:

Condition	Corrective Action
GA > Gn	Cut the plate back to Gn (Case I)
Ga > Gw	Build up to the required bevel using a backing strip (Case II)
$Gn \geq Ga \leq Gw$	No correction is necessary

A plot of the errors found in the measurements of the butt welds in this example would result in a distribution similar to this:

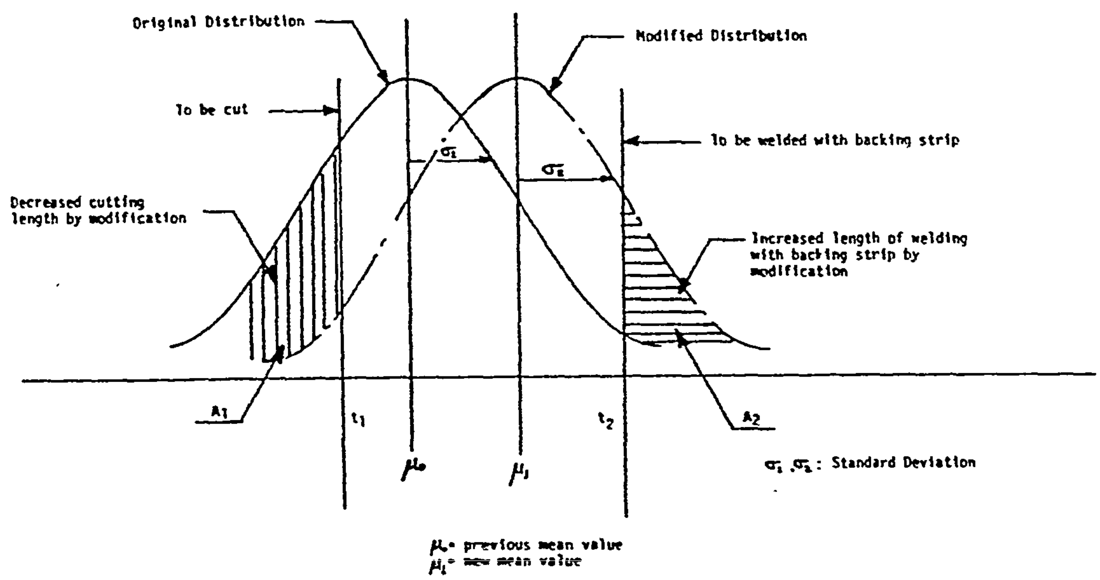


$\mu = \bar{X}$ = Mean (average)
σ = Standard deviation (calculated by formula)
t_1 = Tolerance value (lower control limit for Gn)
t_2 = Tolerance value (upper control limit for Gw)
A_1 = Area of curve beyond tl, indicating probability of errors for values beyond Gn
A_2 = Area of curve beyond t2, indicating probability of errors for values beyond Gw

The shaded area indicates the probability that a measured gap will be beyond acceptable limits, or tolerances. By applying statistical means, this area can be intentionally changed simply by shifting the mean value.

To illustrate the merit of this feature of statistics, suppose it is preferable to weld with a backing strip than to gas cut in order to correct errors. The objective in such a case (after accepting the fact that a certain percentage of errors will occur) would be to increase the likelihood of errors requiring welding for correction, or decreasing the likelihood of errors requiring cutting. The effect of a shift in the distribution of errors would result in a modification of the normal distribution curve as follows:

Distribution of Errors



The shaded areas in this illustration indicate the differences in amount of errors expected to be found in each case, as caused by the shift in mean value. With a shift of the curve and standard deviation, and retention of t_1 and t_2 values, the modified distribution is the same but the area A_2 is smaller than area A_1. This means there was some increase in welding with backing strips to correct errors while there was a greater degrease in cutting corrections required.

In summary, this exercise illustrates the effect of changing a fabrication method to achieve a desired type of error correction. By examining the actions required to correct errors, the method can be changed in such a manner that the errors will be shifted in the direction of the easiest corrective measures. The number of errors were not changed, but the ratio of errors by the two causes were changed. Through random sampling techniques and statistical analysis, the effect of these changes can be predicted, measured, and followed up through feedback analysis.

Accuracy Control Engineers at IHI follow a simplistic but highly effective regimen of "Plan - Dc - See - Action" wherein they accomplish the planning, observe the production operation(s) accomplished under such planning, and, based on the data accumulated from such observations and from Accuracy Control prescribed measurements, take the necessary action to remedy or perfect the production method to achieve the desired results.

From analysis of the measurement data, appropriate action is taken by the Accuracy Control Engineer through feedback of information to the applicable department or group. This feedback is a vital loop in the overall Accuracy Control scheme and not only prevents errors from recurring, but provides the action necessary to the continuing improvement of product and production system. Examples of this feedback are: a change to the dimension of added material requires a modification to the working drawing, therefore, Engineering is so notified; an addition of Baselines in the output of the mold loft requires feedback to the loft; a change in the fabrication method, or the platform at assembly or welding procedure requires feedback to Production and to the Planning and Design Staff responsible for a given workshop.

4.6 ... APPLICATIONS

Prior to the Technlogy Transfer Program, Livingston had not published formal tolerance standards for internal use *in* hull construction methods. There were plans to develop these standards, relying heavily on the Survey OF Structural Tolerances in the United States Commercial Shipbuilding Industry compiled by the Ship Structure Committee and published in 1978.

The adoption of unitized ... vessels increases the importance of tolerance standards to insure ... ectability of assembled units. IHI engineers contributed to ... ment of tolerance standards for Levirgston compatible with the unit system being implemented, by their input and their comments on draft proposals. Livingston .engineers reviewed lHI's Tolerance standards published in the aforementioned docu-

SPAIS (Shipbuilding Process and Inspection Standard) and Standard Tolerance for keeping High Accuracy at IHI-Aioi Shipyard, for ideas on types of standards, format of information, and specific tolerance . allowances.

Livingston published standards for welding and for joint details, including tolerance limit values, prior to TTP. These standards specify edge preparation fitting and welding techniques as allowed in the welding procedure qualification process. Since inception of TTP, Livingston has issued tolerance standards for hull construction in the areas of hull details (e.g., fitting accuracy), ship design (overall hull dimensional deviations), in piping (e.g., butt weld fitting material requirements)., and in flat panel assembly (e.g., structural alignment). Examples of Livingston's tolerance standards are given as Figures 4-12 and 4-13.

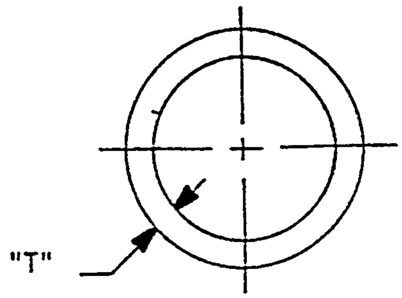
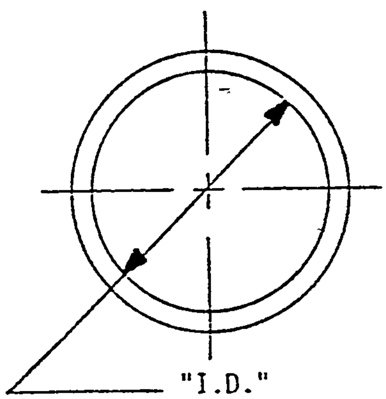
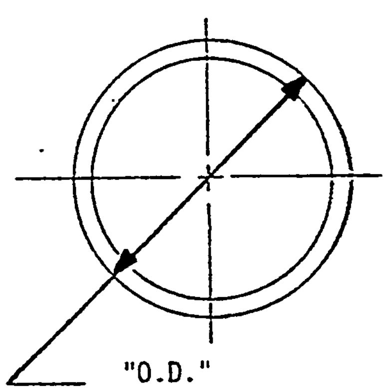
OBJECT		MATERIAL		
TYPE	SUB TYPE	ITEM	TOLERANCE LIMIT	REMARKS
PIPE AND BUTT WELD FITTINGS	WALL THICKNESS		T = THICKNESS THE WALL THICKNESS SHALL NOT AT ANY POINT BE LESS THAN 87 1/2% OF THE NOMINAL THICKNESS.	PER ANSI B16.9
	INSIDE AND OUTSIDE DIAMETERS		I. D. = INSIDE DIA. A. UP TO 2 1/2" - ± 1/32" B. 3" TO 8" - ± 1/16" C. 10" TO 18" - ± 1/8" D. 20" TO 48" - ± 3/16"	PER ANSI B16.9
			O.D. = OUTSIDE DIA. A. UP TO 2 1/2" +1/16" - 1/32" B. 3" TO 4" +1/16" -1/16" C. 5" TC 8" +3/32" -1/16" D. 10" TO 18" +5/32 -1/8" E. 20" TO 48" +1/4" -3/16"	PER ANSI B16.9

FIGURE 4-12 LEVINGSTON TOLERANCE STANDARDS - EXAMPLE

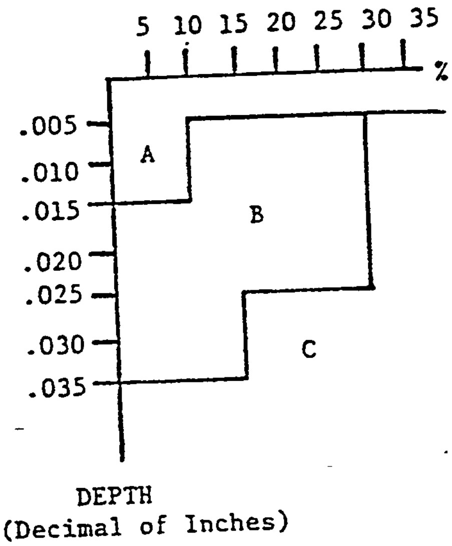
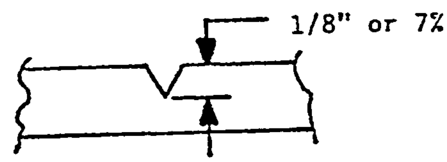
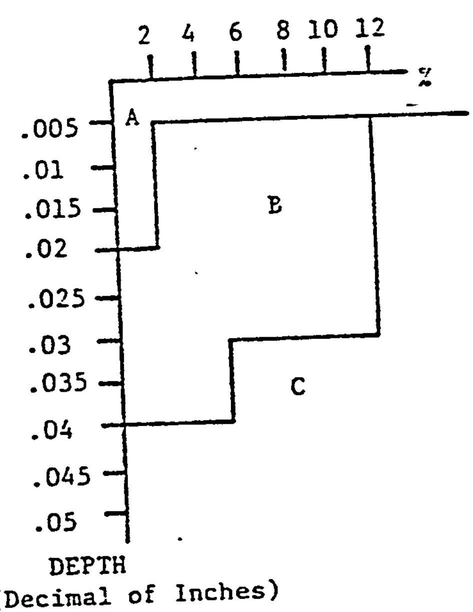
		MATERIAL	
TYPE	SUB TYPE	ITEM	REMARKS
SURFACE FLAW	PIT	SURFACE AREA RATIO 	1) GRADE "A" - SLIGHT NO REPAIR NECESSARY. GRADE "B" - MEDIUM DISORDER, REPAIR IF NECESSARY. GRADE "C"- SERIOUS DISORDER NEEDS REPAIR. 2) REPAIR METHOD - GRIND OR WELD & GRIND. MILL STANDARD = 1/8" or 7% OF PLATE THICKNESS. 
	FLAKING	SURFACE AREA RATIO 	1) GRADE "A" - SLIGHT NO REPAIR NECESSARY. GRADE "B" - MEDIUM DISORDER REPAIR IF NECESSARY. GRADE "C" - SERIOUS DISORDER. NEEDS REPAIR. 2) REPAIR METHOD - SAME AS PIT REPAIR

FIGURE 4-13 LEVINGSTON TOLERANCE STANDARDS - EXAMPLE

Instructions for repair of out-of-tolerance errors are included in the "Remarks" column of this form. These standards were issued with the notation that every effort is still expected to be made to obtain required dimensions. It is further stated that the tolerances are an indication of the lowest acceptable level of performance and not to be interpreted as an allowable standard for everyday work.

Livingston's tolerance standards were developed using experience and knowledge of their personnel as well as a number of external sources. As mentioned earlier, IHI input and the 1978 Structural Tolerance Survey were reviewed. In addition, other sources included:

ABS (American Bureau of Shipping)
USCG (United States Coast Guard)
Navy (Navy Ships Military Standards)
ASTM (American Society for Testing & Materials)
ANSI (American National Standards Institute)
IMCO (Intergovernmental Maritime Consultive Organization

A committee was formed with representatives from the Engineering, Accuracy Control, Production, Industrial Engineering and Manufacturing Engineering Departments to develop Livingston's tolerance standards. All known sources of published standards were used as guidelines to determine the standards for Livingston. However, there is very little in the way of published tolerance-standards. Vague terms such as "in accordance with good shipbuilding practice" are the most commonly occurring specifics. The final standards arrived at are unique to Livingston due to equipment used, construction methods, inspection methods, accuracy objectives, etc. The IHI standards reviewed during Livingston's research were found to be generally tighter than those set by Livingston.

In the future, Livingston anticipates the development of tolerance standards in areas beyond those already established; such as those

4.7 CONCLUSION

Tolerance standards for a given shipyard must reflect the conditions, equipment and methods of operation at that particular facility. The standards are invaluable to maintain a satisfactory program of accurate workmanship. The data collection system used to develop these standards, the flow of information *to* appropriate departments, and the standards devised by classification groups or used at other locations are transferable as guidelines for a facility to use in initiating its own program. The IHI system was discovered to be very comprehensive and containing rigid standards by comparison to Livingston's past guidelines for tolerances.

The tolerance standards program at IHI ties in directly with the Accuracy Control function within their Quality Control division. Their Accuracy Control function comprises three elements:

Planning
Field Activity
Data Analysis and Information Feedback

The tolerance standards at IHI have been developed over a period of many years and several series-runs of ships. This results in little, if any, modification of tolerance standards for a new ship contracted. In cases where tolerances need to be changed, volumes of data and vast knowledge from personnel are available to draw upon.

The connection between tolerance standards and each of the three elements of accuracy control may be summarized as follows:

Planning Activity: One of the two types of control for tolerance standards, i.e., either regular or special control, is applied at the planning stage. Tolerances requiring special control are identified for application to vital measurement points, vital dimensions, and base lines.

Field Activity: Tolerance standards specifying allowable limits, and measurement standards specifying tools and techniques to use, are prepared and recorded on “check sheet” forms.

Feedback Activity: Tolerances are revised as necessary to reflect changes in design, fabrication method, inspection method, or equipment used. Records of data, statistical analysis and graphs are used to provide feedback of information to prevent recurrence of errors and to assist in devising improved methods of operation.

Livingston benefitted significantly from the institution of IHI’s Accuracy Control concept. A program for development of tolerance standards, related to this overall system, has been initiated at Livingston with issuance of some tolerance standards, but a number of other areas are still targeted for future extension of this idea.

The check sheets used at Livingston, similar to the forms used at IHI, document the data collected during routine inspections. This data is useful to establish the types and occurrences of out-of-tolerance errors. A dimension found to be out-of-tolerance is so noted on the designated space on the check sheet, along with the required corrective action. Compilation of this data provides a feedback system with two primary objectives:

1) Analysis of Data: to insure correct marriage of units; to provide data for graphs as reference both for fit-up of units as they are erected and for future hull construction; and for assistance toward making decisions on approval of measured pieces.

2) Improvements in Operations: to revise tolerances as necessary in accordance with information supplied by check sheets; to suggest improved equipment and/or facilities; to determine optimum construction methods.

The feedback system is an essential ingredient for developing, maintaining and revising tolerance standards. The system relies on a substantial amount of data collection, but amply compensates for itself by providing information vital to sustaining a reliable accuracy control program. This becomes especially visible at the assembly and erection stages, where ease of fit-up is directly related to the accuracy of work in the preceding stages. Improvements in this area easily justify a comprehensive program of well-established tolerance standards for any shipyard.

SECTION 5

PROCESS STANDARDS

5.1 INTRODUCTION

The term “process standard” can have a wide variety of definitions, and may be used in both broad and restrictive contexts. For the purpose of this section, a process standard is defined as follows:

A process standard is an established method prescribing a uniform sequence for performing an operation or set of operations.

This definition indicates that a “process standard” and a “standard “ process” are terms that may be used interchangeably-. This definition is presented in order to distinguish a process standard from a cost standard as they are described in this report. The main distinction canbe expressed by stating that a measurement of performance of a “process standard” results in a “cost standard”.

This difference between “process standard” and “cost standard” is explained in detail at this point because the term “process standard” was often used by IHI in such a manner that it could be considered inclusive of both terms. The discussions applicable to process standards are contained in this section of the report. However, some of IHI’s recommendations and related charts included in the section on cost standards are referred to as “process standards”.

The term “process” is also used both broadly and restrictively. To understand the meaning of this term as used in this report, the following definition is offered:

A Process is an operation or sequence of operations performed on a component which changes the characteristics of the component.

In this context, then, a process may be broad (eg. cutting, assembly) or specific (N/C cutting, flat panel assembly).

IHI maintains a wealth of process standards in the forms of manuals, operating guidelines, written procedures, instructions, etc., which are used throughout the shipbuilding process. They also maintain numerous records, lists and logbooks which are used to develop these standards.

Each shipyard has different methods and techniques for shipbuilding caused by variations in facilities, ship types, throughput capabilities, and other differences. However, the basic shipbuilding process is quite universal. It is important for each shipyard to designate acceptable, uniform methods to be used to achieve the most satisfactory results for that particular facility. This is the purpose of the process standards as they apply to specified operations.

IHI expresses the basic considerations necessary to implement effective steel construction in the following manner:

1) For smooth progress of erection work, every unit of hull construction must be prepared on schedule.

2) For smooth progress of each stage of production, the necessary materials for each stage must be prepared on schedule.

3) Although the processes vary between shipyards, a basic concept of "group technology" can be applied to any process flow examination.

The group technology concept advanced by the Japanese refers to the total scope of activities extending beyond just the standardization of processes. Group technology refers to the breakdown of a whole into component parts. In shipbuilding, this corresponds to breaking the ship into units at the design stage and segmenting the shipyard layout by process definition. These applications of group technology are interrelated by coordination of efforts between design, material procurement, process utilization and production needs. A primary objective of this unitization concept is the maximum utilization of standardization.

The group technology concept is visible in the Japanese organization. Field engineers fall within the Production organization. These engineers accomplish the detail planning, scheduling, trouble shooting and coordination of activities within each workshop. They develop all the lower level information required to procure, fabricate, sub-assemble, assemble and erect the component parts of a ship. From their data collection, technical-expertise and thorough knowledge of the operations within their workshops, they formulate the process standards used in this area. Their close interaction with workshop personnel and the requirement for their development of process measurement and control graphs (eg. manhours per inter of weld deposit), provides constant opportunity for them to analyze improved methods for doing virtually every job in the shipyard. The improvement of productivity is one of their express objectives, and the development and use of process standards is one of their primary means of achieving this objective. Further discussion of the group concept can be found in the TTP Final Report on industrial Relations.

The process flow charts as organized at IHI are provided as Figures 5-1 through 5-7. The charts incorporate steel and outfitting processes into the following categories:

MOLD LOFT

This work is divided into three classifications:

1) Panel

2) Longitudinal Frame

3) Internal Member

The internal member classification is further divided into EPM or NC processes.

These classifications were determined on the basis of similarity in techniques involved.

FABRICATION

This consists of four categories:

1) Panel

2) Internal Members

3) Angle

4) Built-up Longitudinal

These are sub-divided into processes according to facilities.

SUB-ASSEMBLY

About one-third of the total assembly weight is produced at this level prior to the start of assembly work.

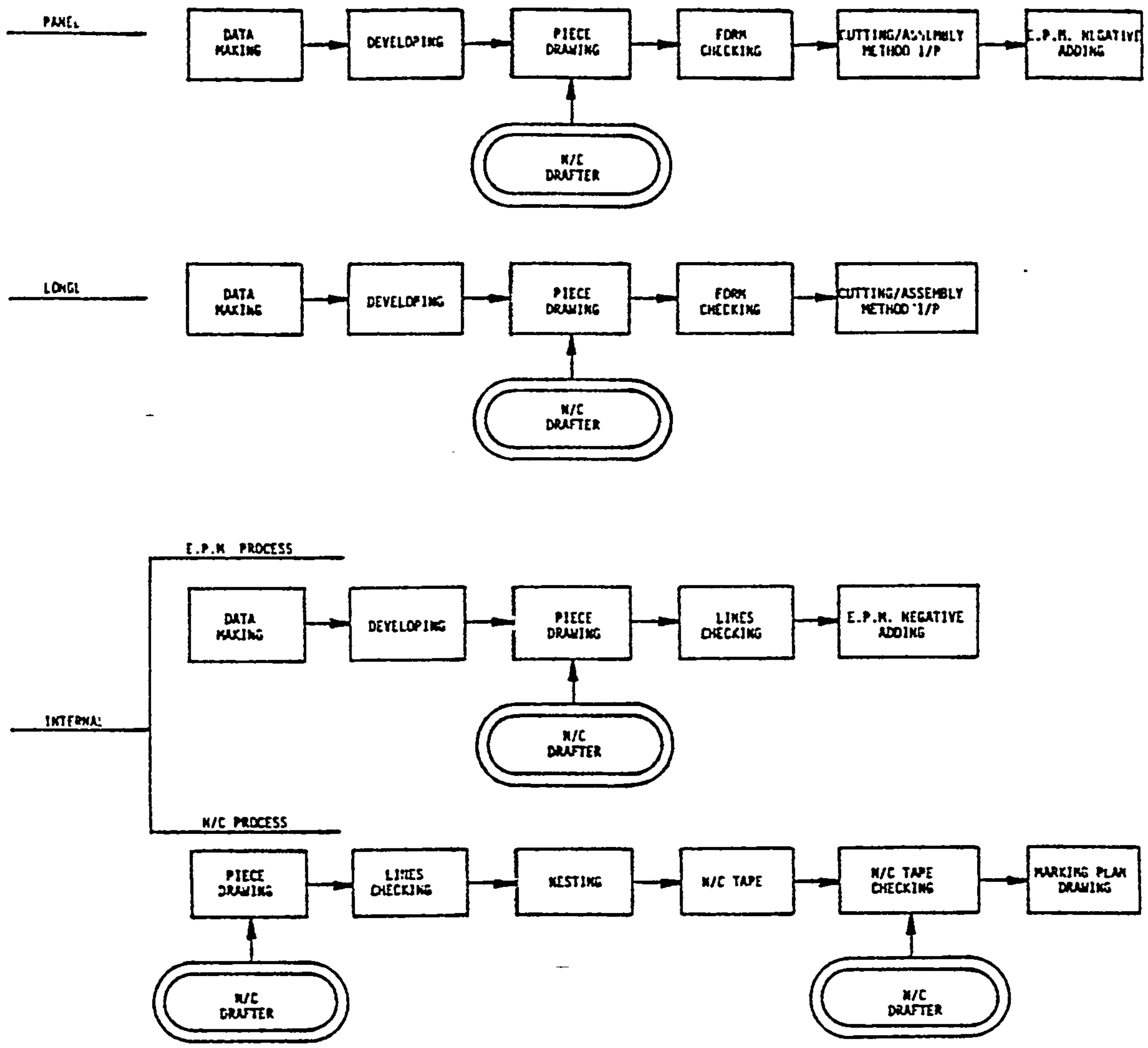
ASSEMBLY

This consists of three categories:

1) Panel Unit

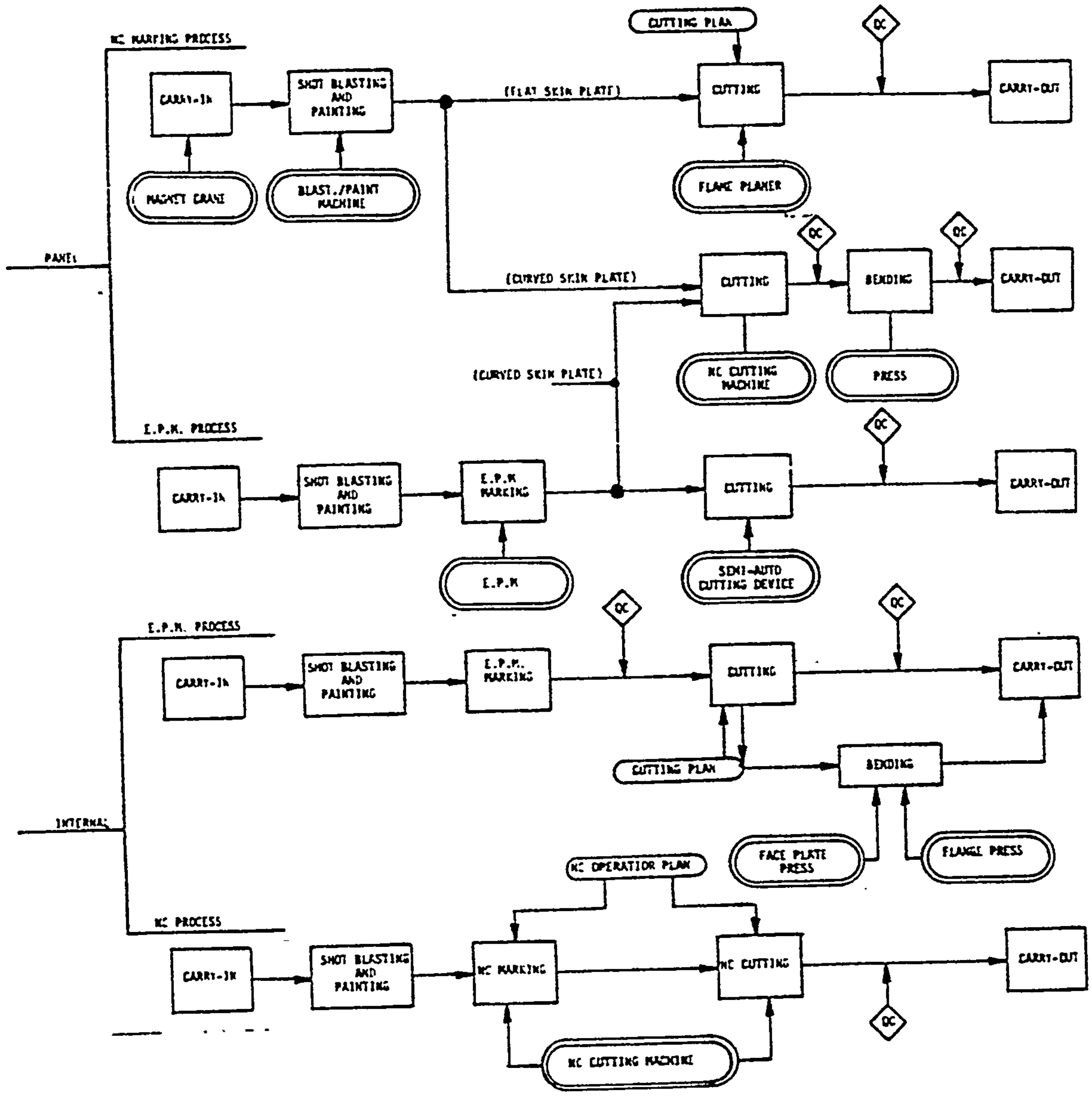
2) Semi-Panel Unit

3) Curved Panel Unit



FLOW CHART OF MOLD LOFTING

FIGURE 5-1



FLOW CHART OF FABRICATION (1/2)

FIGURE 5-2

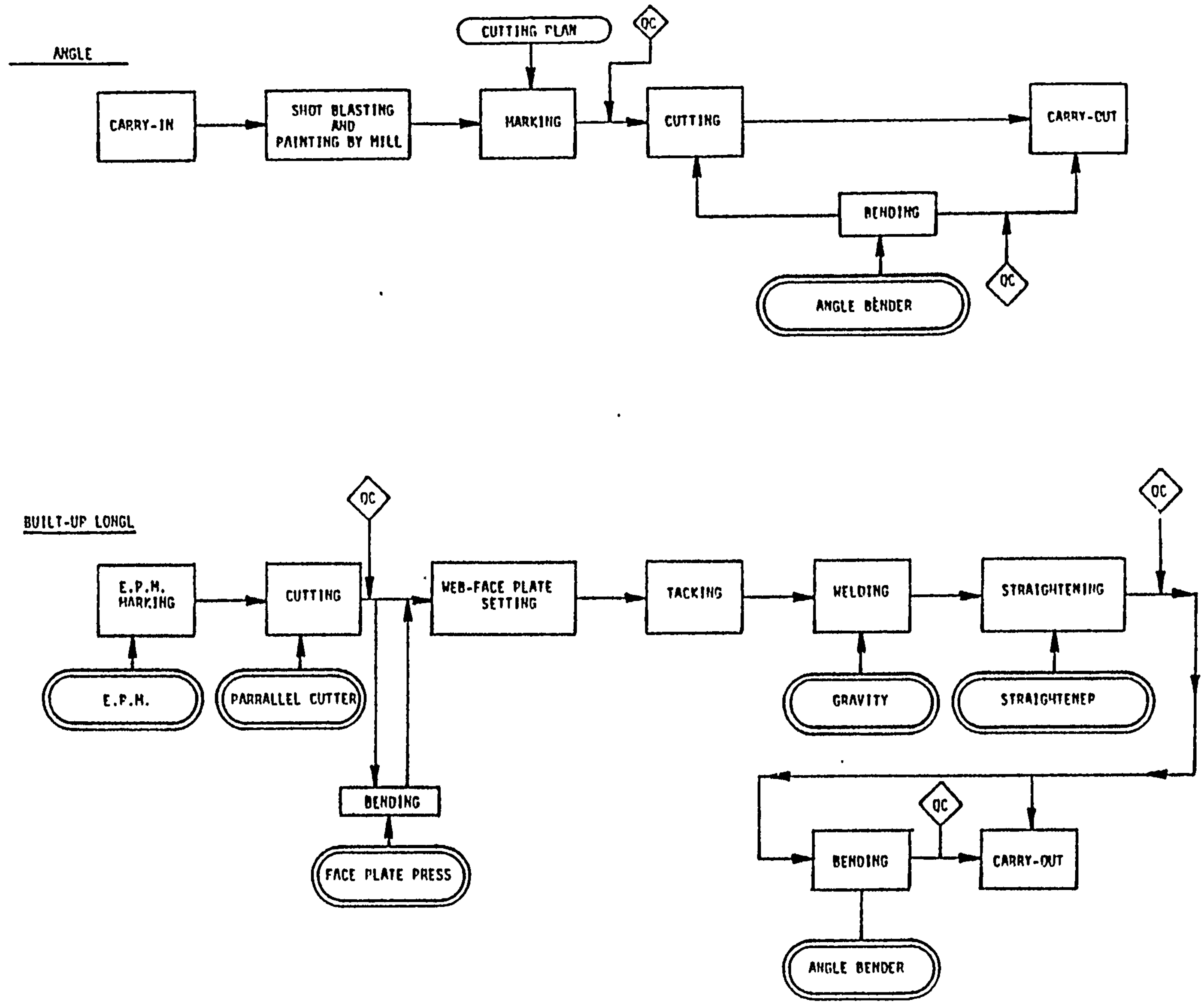
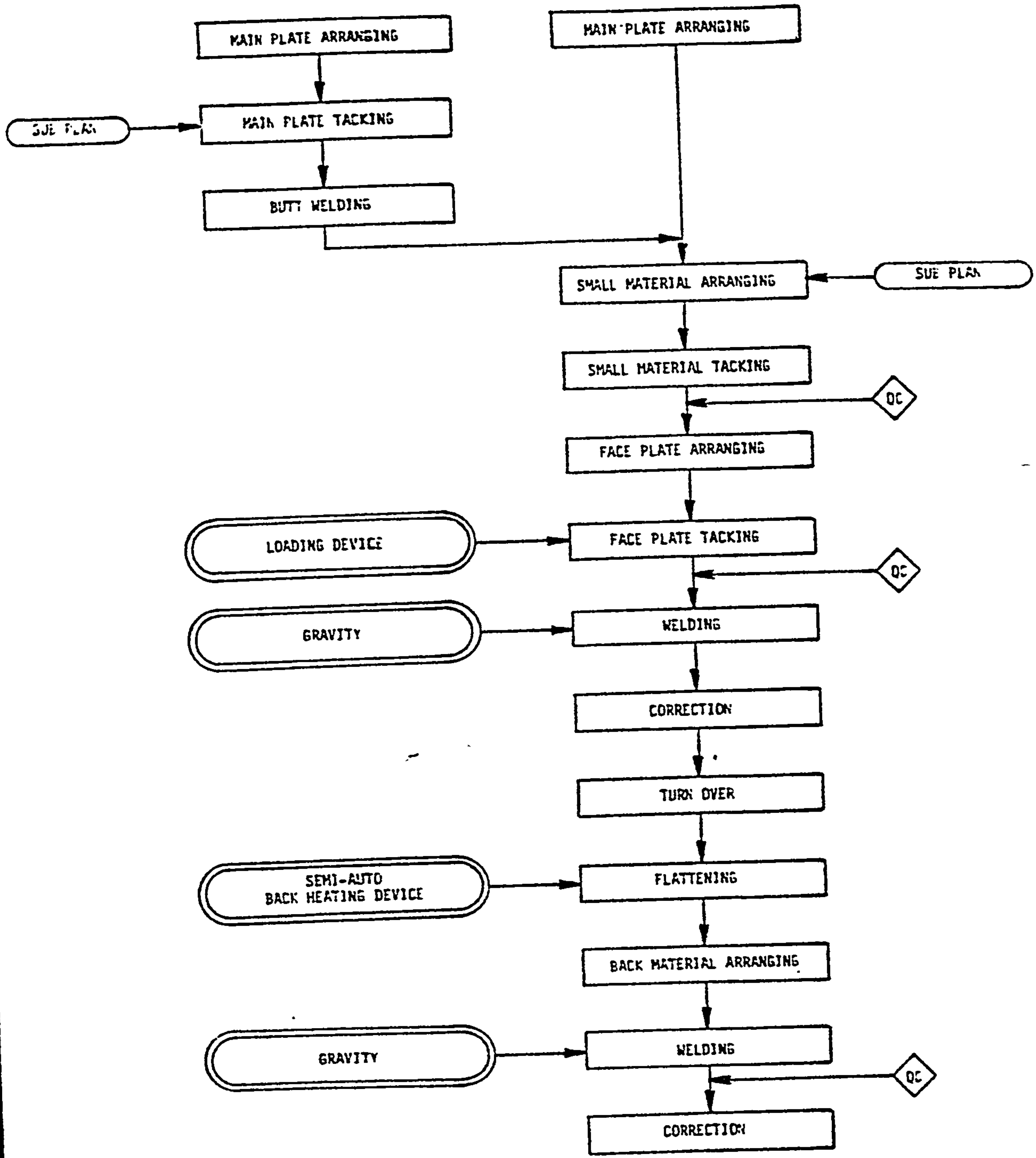
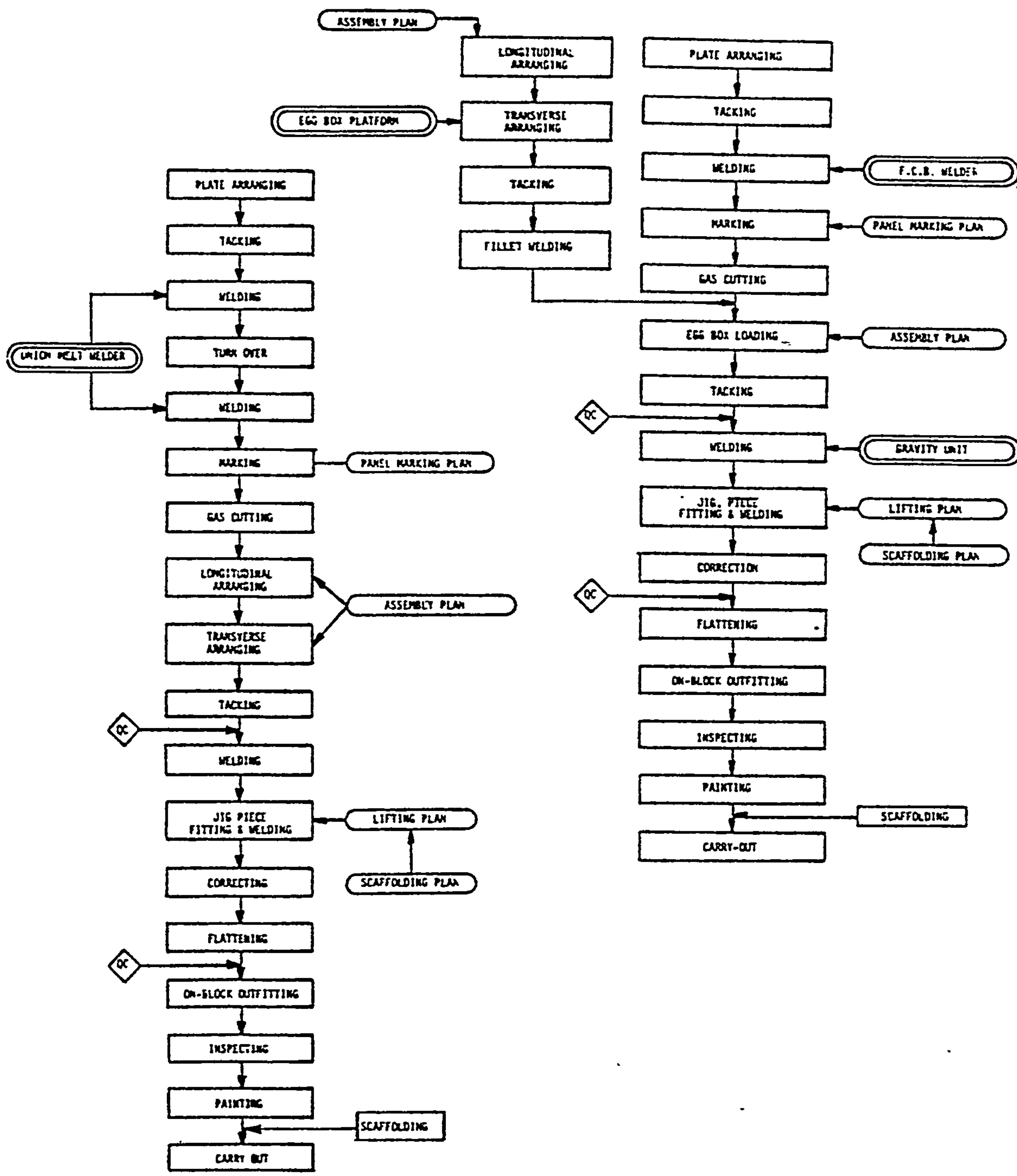


FIGURE 5-3 FLOW CHART OF FABRICATION



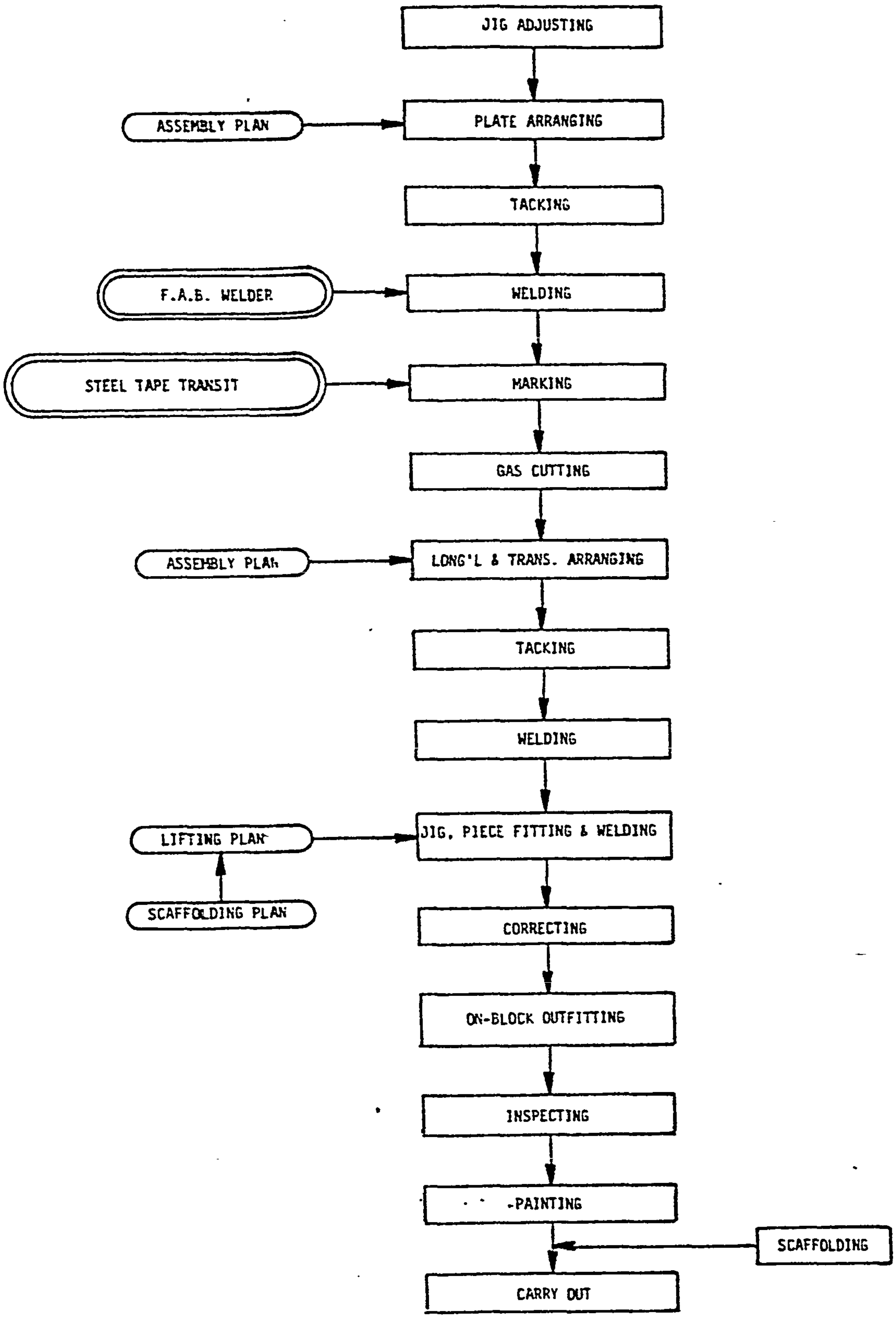
FLOW CHART OF SUBASSEMBLY

FIGURE 5-4



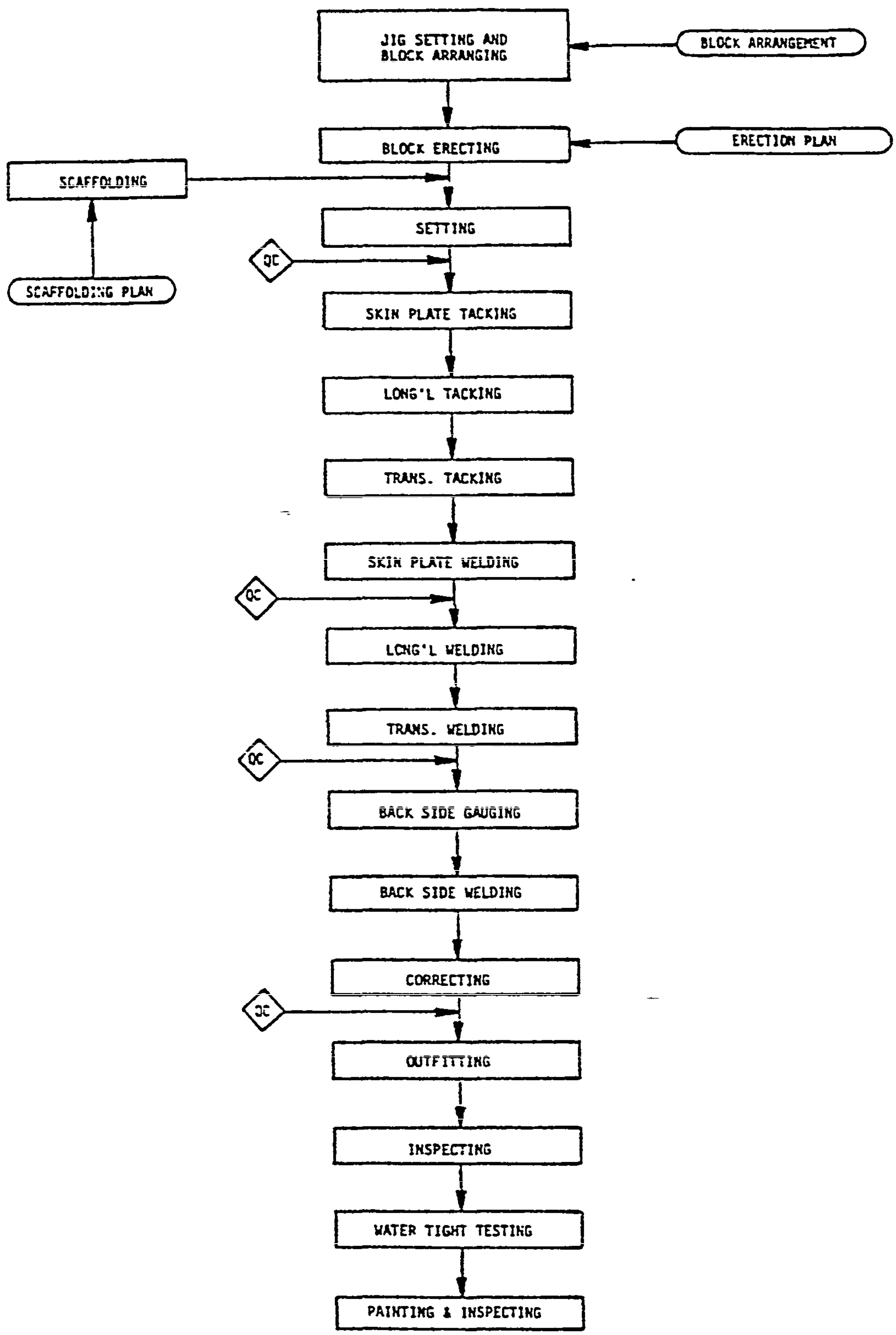
FLOW CHART OF FLAT PANEL ASSEMBLY

FIGURE 5-5



FLOW CHART OF CURVED PANEL ASSEMBLY

FIGURE 5-6



FLOW CHART OF ERECTION

FIGURE 5-7

These processes are classified in this manner to achieve the highest productivity for each type through full utilization of specific facilities for those processes.

ERECTION

This consists of the work involved from arrangement of the jig to the inspection activities.

5.2 SIGNIFICANT DIFFERENCES (IHI VS. LIVINGSTON) & SUGGESTED IMPROVEMENTS

IHI pointed out the significant differences between Livingston and IHI. The fundamental difference in organizations concerning application of group technology was reiterated. Within the processes themselves, the greatest points of differences were found to be in the sub-assembly and assembly areas. Specific differences and recommended improvements for standardization of the processes included the following:

1) Maximize assembly of small pieces at the sub-assembly stage, thereby decreasing the amount of this minute work required at assembly stages.

2) Classification of assembly work into the categories previously listed with the following objectives:

   -Maximum utilization of facilities to obtain the highest productivity.

   -Achievement of the most performance by means of having workers permanently stationed at fixed work sites.

3) Utilization of welding in the flat position, in order to obtain good performance and high productivity.

In the area of outfitting, specific recommendations made by IHI to improve on the standardization concept concerned greater utilization of:

1) Pre-Outfitting: Module Stage

2) Pre-Outfitting: On-Unit Stage

3) Pipe Fabrication: In the Shop

Specific recommendations concerning improvement on the individual processes are covered in the remainder of this section. The relationships between process standards, cost standards and methods improvements overlap in these discussions, so that a preview of the material covered in the TTP Final Report on Facilities and Industrial Engineering aids in comprehension of the remainder of this report. Also, the development of process standards is closely linked to the “process lane” concept recommended by IHI, which was adopted at Livingston as a “gate system”. This concept is thoroughly discussed in the TTP Final Report on Planning and Production Control, and should be reviewed before the remainder of this report can be understood.

Figure 5-8 illustrates the general concept of the Gate System implemented at Livingston as it applies to shipbuilding. This concept is divided into the plans, schedules and operating procedures shown on Figure 5-9. The aspects of the gate system are further detailed into individual elements as listed in Figure 5-10. This section on Process Standards is specifically aimed at the aspect regarding standard work flow in each area, particularly the detail procedures for each area. This procedure requires analysis of the facilities and the work breakdown assignments, examination of methods for their description, and improvement and identification of the skills and equipment needed. The process standards will then be used to develop time standards, cost standards and manpower requirements to analyze productivity and to provide data for planning and scheduling purposes. The objective of standardizing processes is to organize procedures in a uniform and repetitious manner for use in formulating accurate schedules in the easiest fashionable manner.

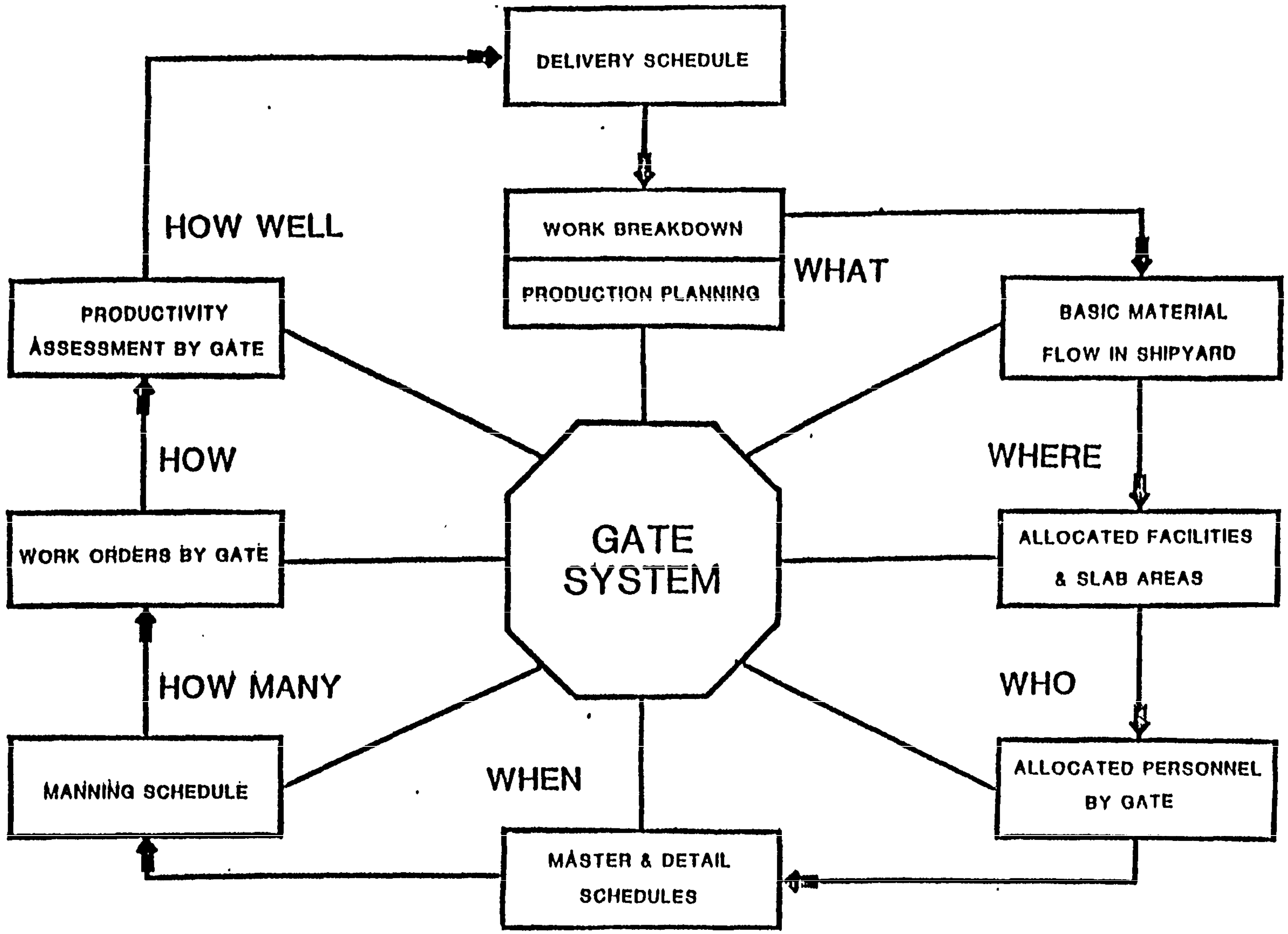
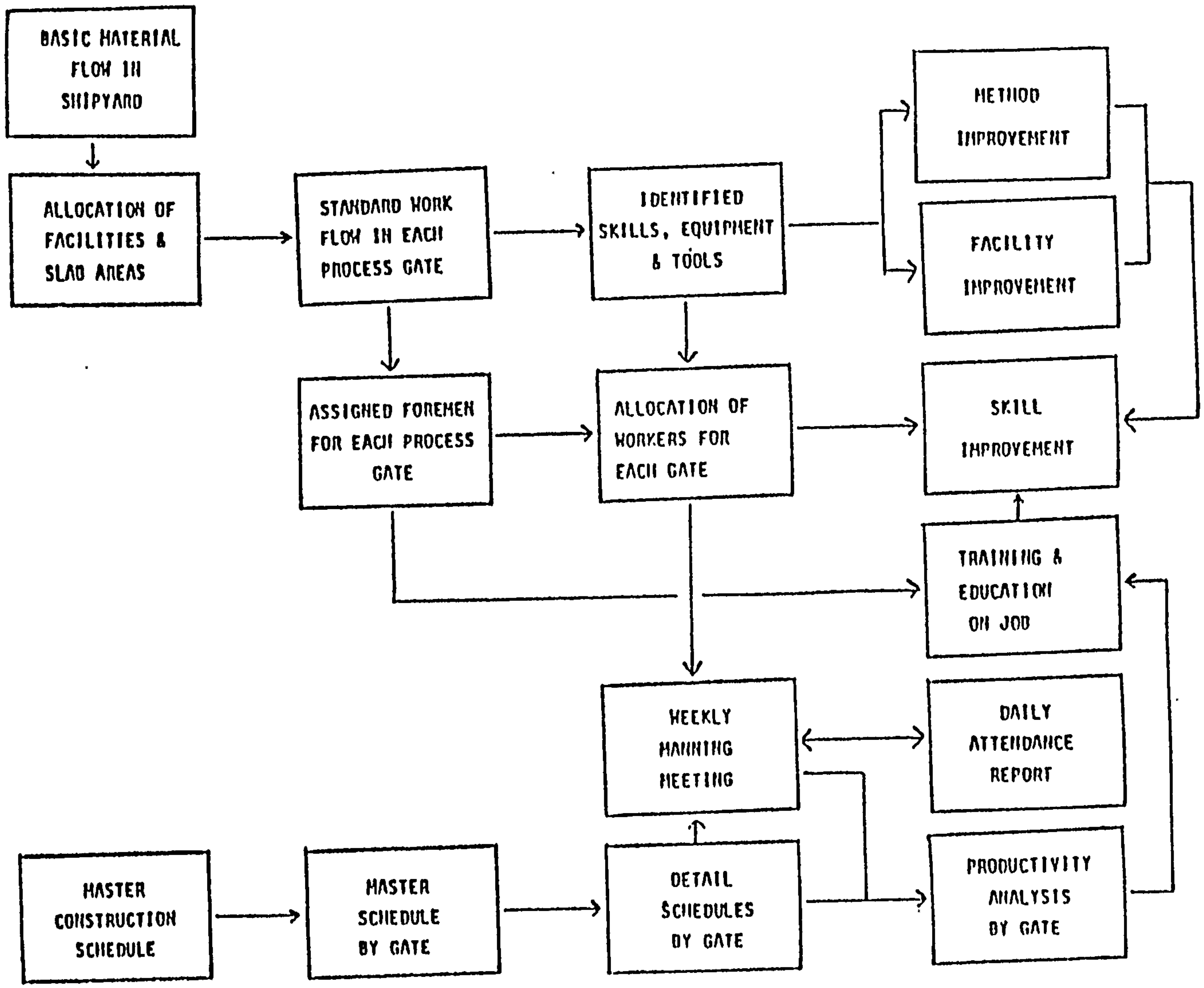


FIGURE 5-8 GATE SYSTEM



CONCEPT OF THE GATE SYSTEM

FIGURE 5-9

ALLOCATION OF FACILS. & SLAB AREAS	STD. WORK FLOW IN EACH AREA	IDENTIFIED SKILLS, EQUIP. & TOOLS	ASSIGNED FOREMEN & WORKERS FOR EACH GATE	SCHEDULING/PRODUCTIVITY ANALYSIS
Work breakdown according to pre-determined facil. assignment	Detail schedules/Procedures for each area	Fixed manpower requirements	Increased efficiency thru non-movement	Master schedule by gate
Scheduling by area	Organized work patterns	Skills available when needed	Group development	Detail schedules within gate (by Station)
Man-loading by area	Housekeeping by resident group	Fixed equipment/Tools requirement	Responsibility/Recognition identification	O/T used to recover schedule
Transportation/Crane requirements planned for each area	Flexibility in worker use & methods	Equipment/Tool maint. by resident group	Tighter supr. control	Output of each gate & station can be measured against plan
Facility impr. requirements readily identifiable			Escalating Skills/Methods	Chronic problems identifiable to specific gate or area
			Schedule Communication	Productivity recognizable by workers
			Workers active toward schedule/quality achievement	
			Group responsibility for area/product	

ASPECTS OF THE GATE SYSTEM

FIGURE 5-10

5.3 PRELIMINARY PLANNING

Planning at the preliminary stage as presented in this discussion is based on the implementation of the gate system. As previously described, an essential ingredient in the establishment of basic procedures is the assignment of areas where similar work is to be performed. This allows flow charts to depict the gates through which a unit will pass in the fabrication and assembly processes.

IHI assessed Livingston's system of reporting and application of the unit division to working procedures. Figure 5-11 represents IHI's evaluation of Livingston's flow of work, and Figure 5-12 illustrates their view of the functions of the records and documents maintained. IHI recommended some additional functions within Livingston's flow system, shown on Figure 5-13, for the purpose of providing more useful data in the planning and scheduling process. This recommended system was perceived by IHI to result in a. revised set of documenting functions, as depicted in Figure 5-14.

The objective of this proposal was to provide a system whereby standardized procedures would be written and utilized to improve scheduling dependability. Reports, records and available data that were recommended to achieve this goal included:

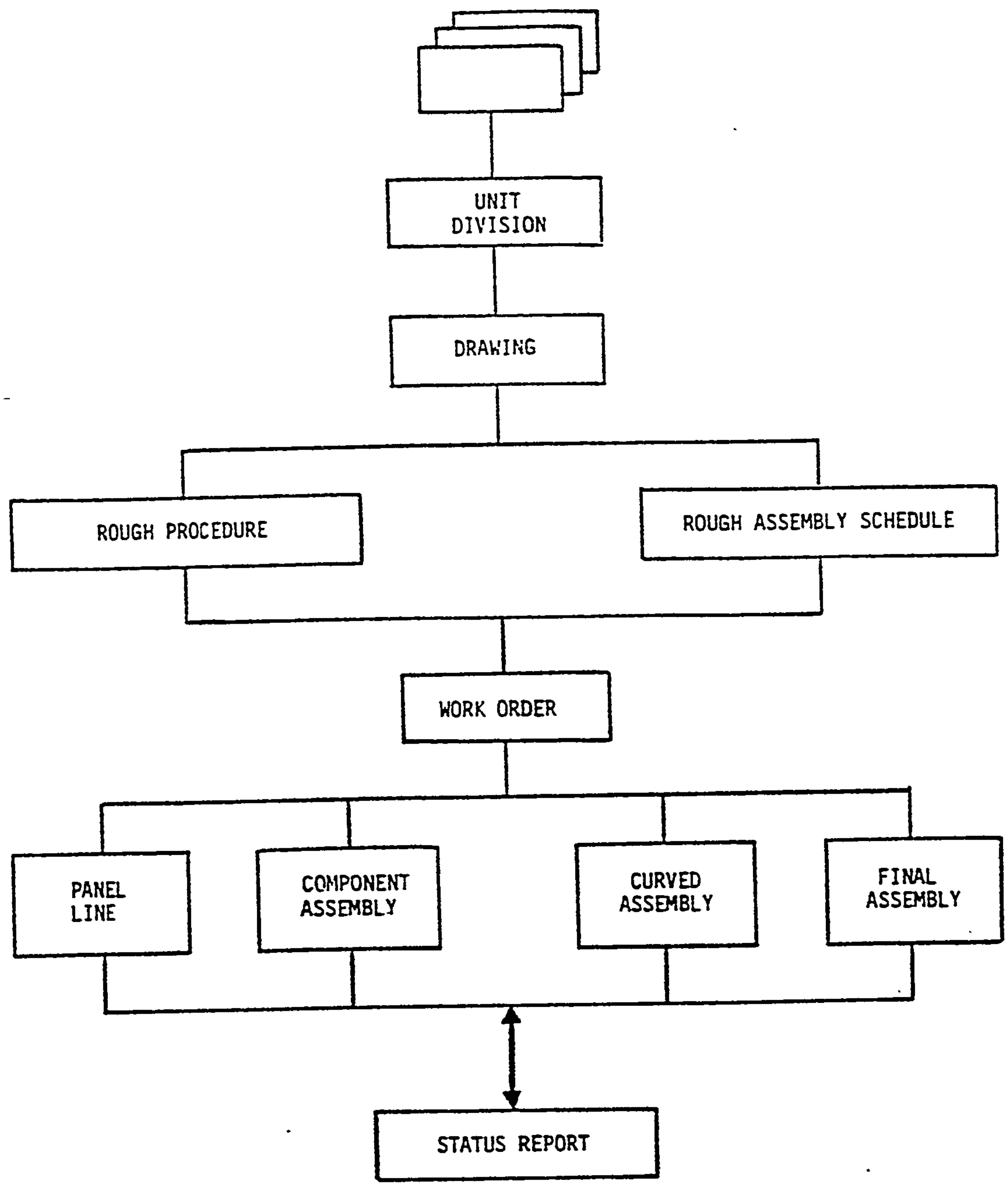
1) Establishment of records to be used in formulating process standards.

2) Creation of Unit Information Lists for use in conjunction with the present Work Order System.

3) Establishment of Fabrication Schedules and Erection Schedules that complement the Assembly Schedules.

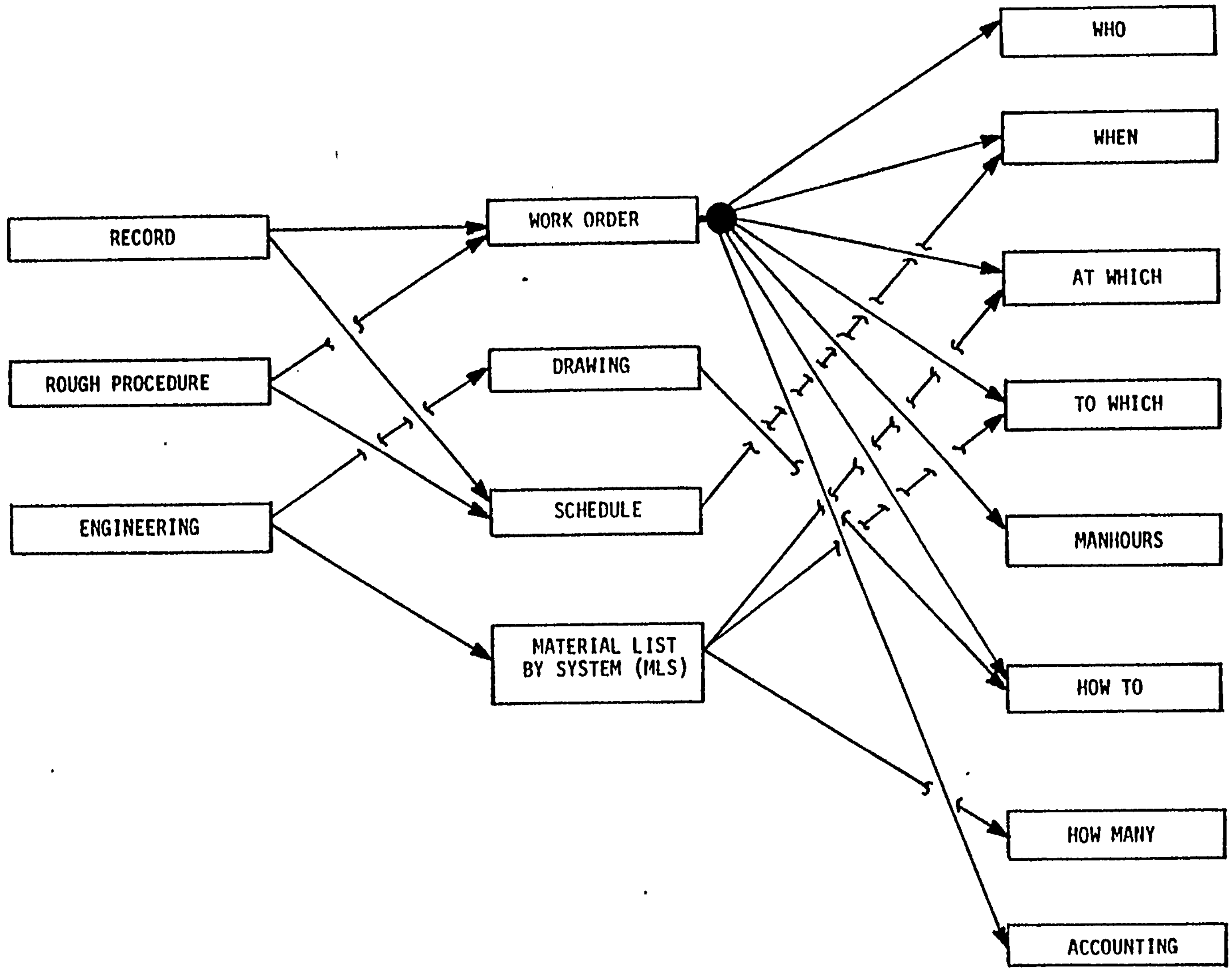
4) Providing a Leveling Process to convert Rough Schedules to confirmed schedules at each stage of construction.

5) Providing detailed assembly procedures to field personnel.



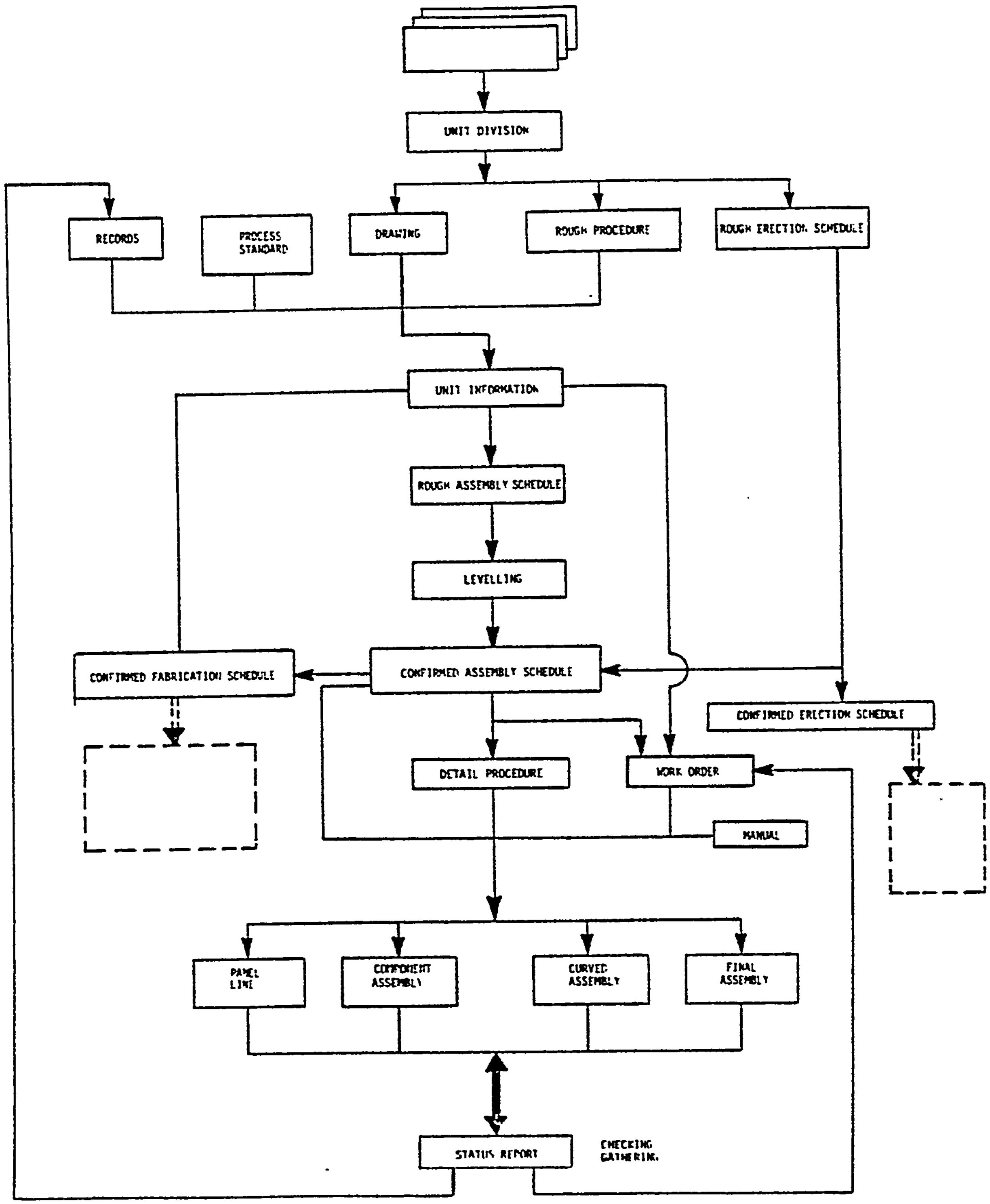
PRESENT PLANNING FLOW

FIGURE 5-11



PRESENT FUNCTION

FIGURE 5-12



RECOMMENDED FLOW OF PLANNING

FIGURE 5-13

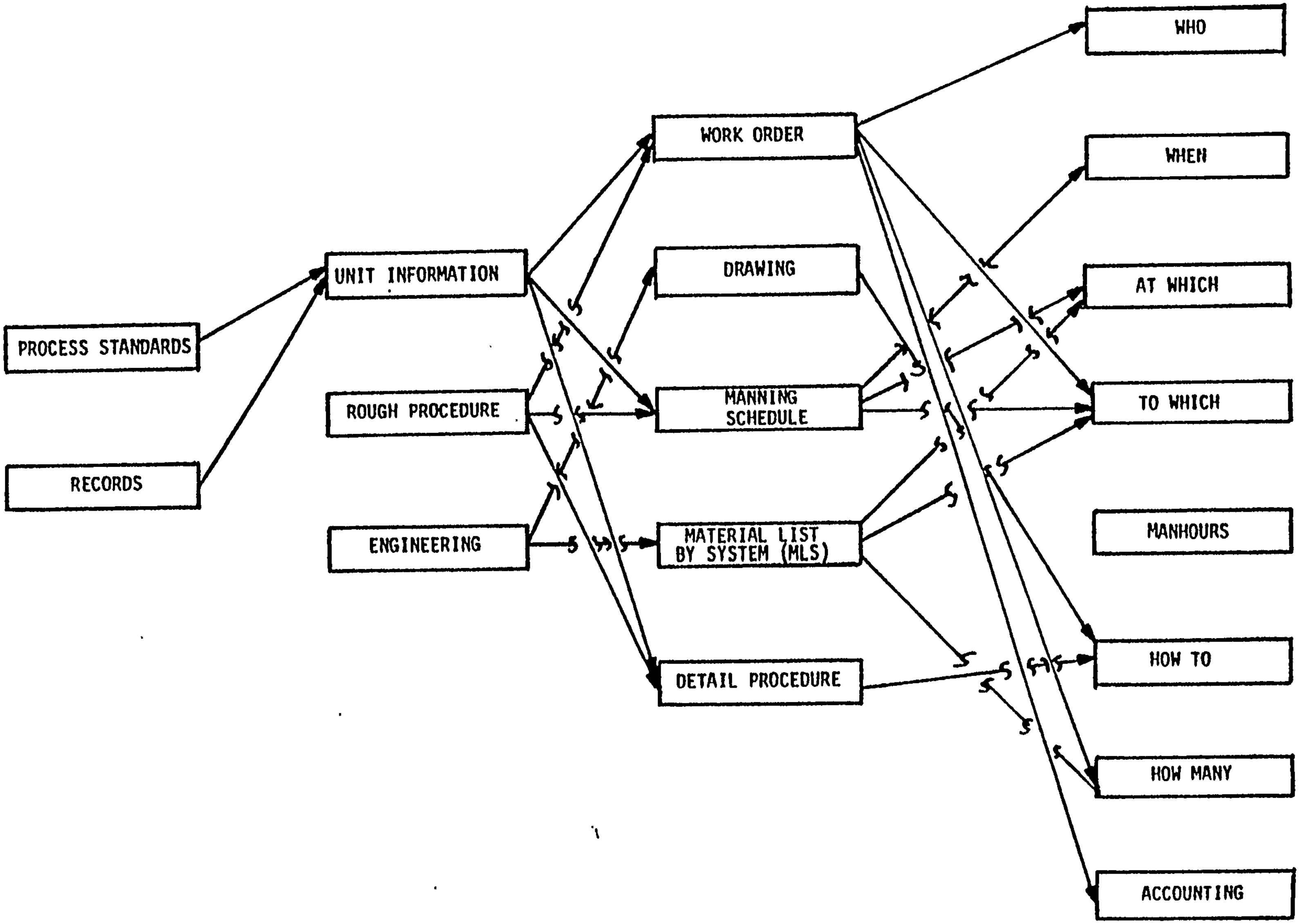


FIGURE 5-14 RECOMMENDED FUNCTION

6) Development of work manuals for use in the field.

7) Formulation of record-keeping that provides feed back as well as data to be used in subsequent planning and scheduling efforts.

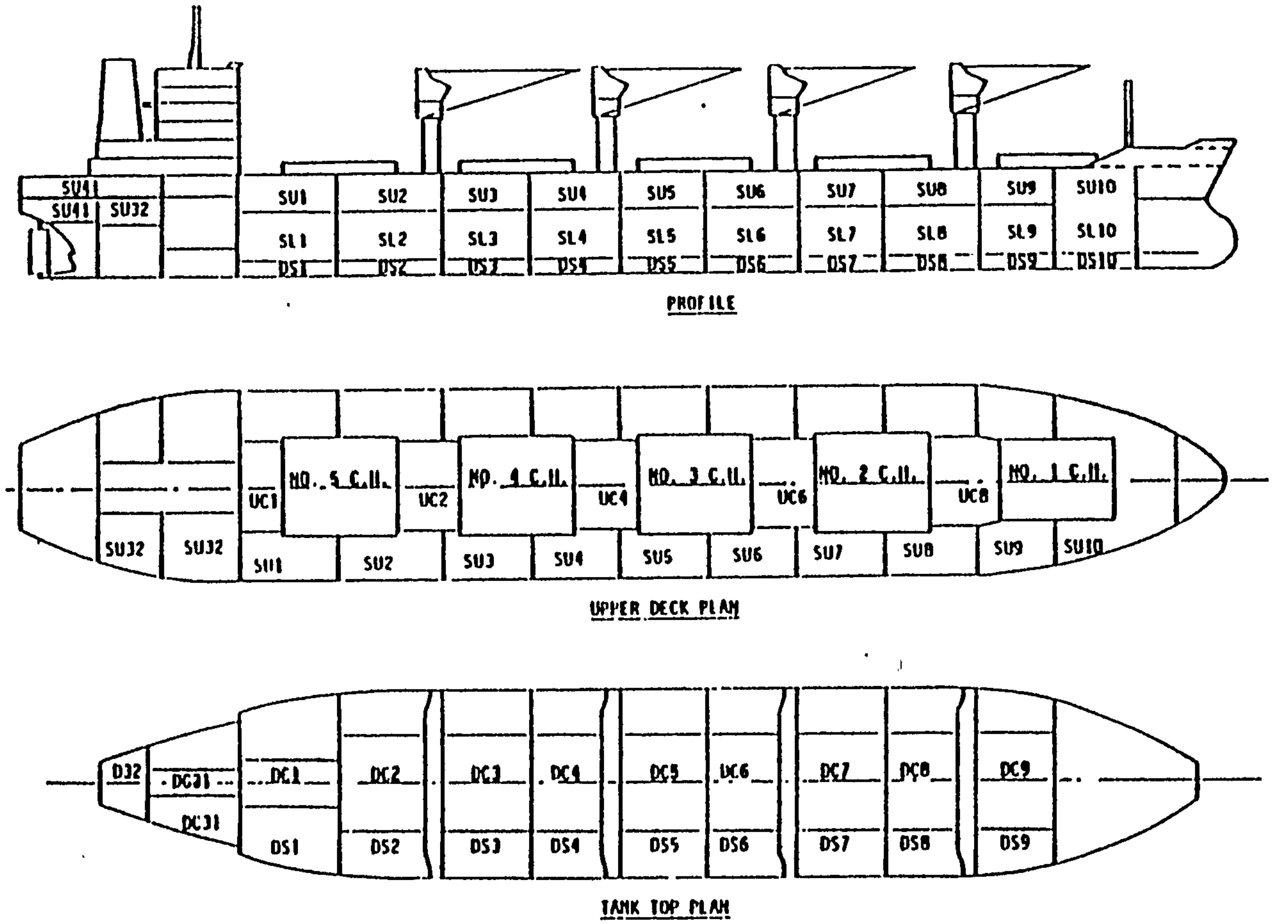
The process standards will deal with the procedures specifying the methods to be employed. These consist of rough procedures drawn up in the early stages as planning efforts in the assignment of work within gates, and the detail procedures designating the method of constructing each assembly unit. These process standards are used to develop cost standards, which are vital elements toward establishment of accurate schedules.

The initial step proposed by IHI to establish standard work procedures involves division of the ship into manageable units that fit--within the capabilities of the available facilites. The main objective at this stage is to maximize efficiency, safety and accuracy at the assembly and erection stages. Figure 5-15 represents a division of the F-32 ship into assembly units.

Following division of the hull into units, typical common-shaped units are sketched to demostrate the assembly sequence of each unit and issued to IHI engineers in a "Guide to the Construction of Units." An example of a typical unit assembly plan is provided as Figure 5-16. The objective of this step is to further promote high productivity and quality through the specification of efficient assembly procedures.

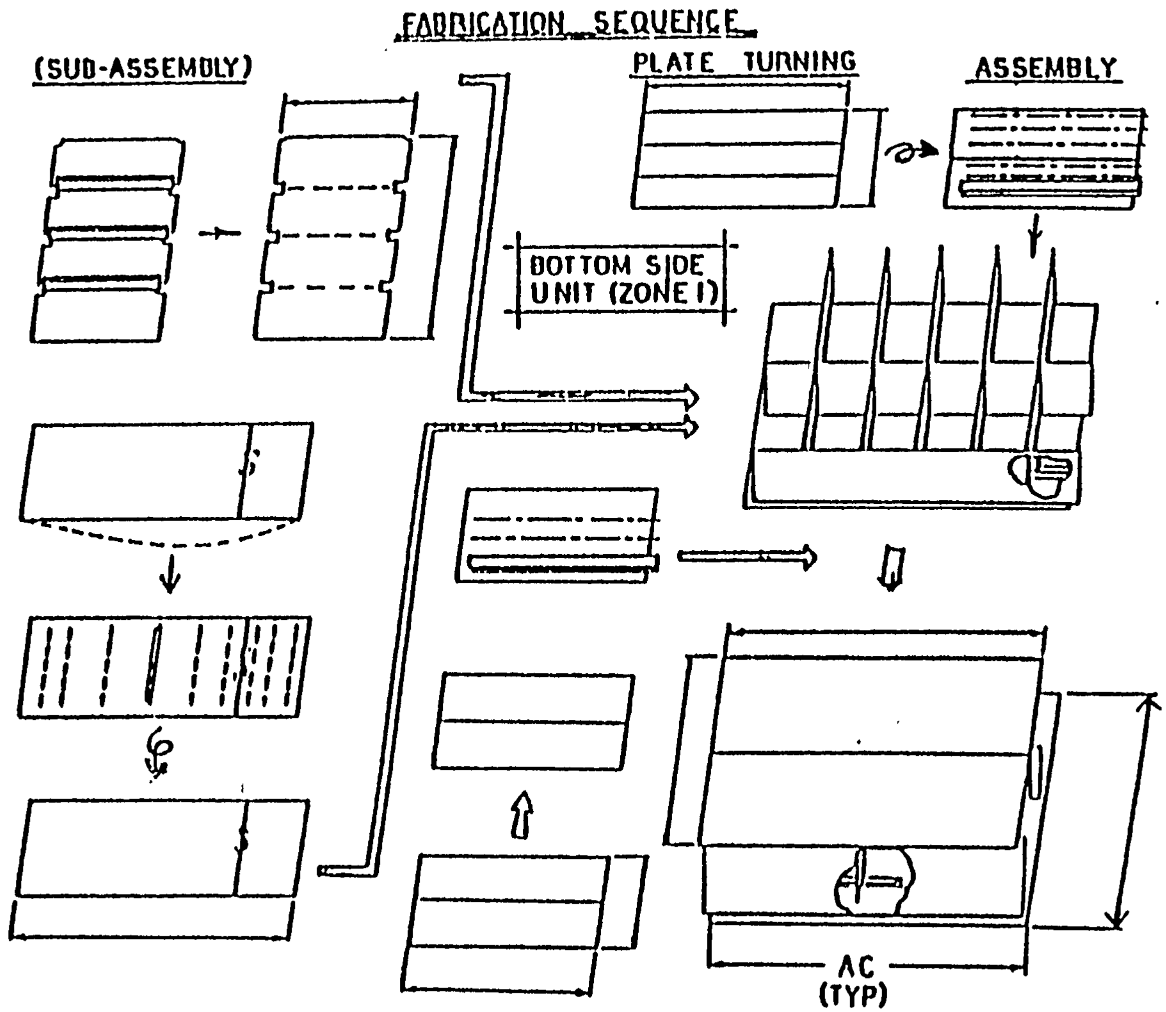
IHI recommended use of forms as shown on the foregoing figures for collection of data essential to development of process standards. These forms include:

Material List by System (MLS): A system-oriented list of materials used for procurement purposes, specifying location of the material within ship zones. An exampie is provided as Figure 5-17.



F-32 UNIT ARRANGEMENT

FIGURE 5-15



UNIT ASSEMBLY PLAN (EXAMPLE)

FIGURE 5-16

MLS 番船別装置部品表

MTL. CODE	DISCRIPTION	PIECE NO.	FAMILY		NO. (NET) / (GROSS)	WT (NET)	引当図番	SUB ZONE	備考
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 R/042V	A32	1	10 10	1040 1040		34X171---0 34X171---0	98 18391 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 R/043V	A32	1	10 10	1040 1040		34X171---0 34X171---0	98 18391 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-025V	A32	1	10 10	1040 1040		14X186---0 14X186---0	98 19177 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-026V	A32	1	10 10	1040 1040		34X186---0 14X186---0	98 19177 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-027V	A32	1	10 10	1040 1040		34X186---0 14X186---0	98 19177 0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00 0-028V	A32	1	10 10	1040 1040		14X186---0 34X186---0	98 19177 0800
403002015	** SUB-TOTAL	**		100				34	
	** SUB-TOTAL	**		100		1040			
403003008	FC S.D.C.GLODE VALVE FC/BC FN 5050GB	31,30,00 S-222V	A32	1	10 10	14 150		14XH1AP--0 14XH1AP--0	98 18392 2 0800
403003008	** SUB-TOTAL	**		10				34	
	** SUB-TOTAL	**		10		150			
403003009	FC S.D.C.GLODE VALVE FC/BC FN 5065GB 922360 362902	32,60,00 FD-019V	A32	1	10 10	213 213		14X110---0 14X110---0	0800
403003009	** SUB-TOTAL	**		10				34	
	** SUB-TOTAL	**		10		213			
403003010	FC S.D.C.GLODE VALVE FC/BC FN 5080GB 922367 364901	33,10,00 FR-201V	A32	1	10 10	27 276		14XH3AP--0 34XH3AP--0	0800

(2205)

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MATERIAL LIST BY SYSTEM

FIGURE 5-17

Unit Information List: This list designates for each unit the physical characteristics of the unit and the process flow, or gate sequence. This list is illustrated by example in Figure 5-18.

Basic Production Flow List: This list is the basic for information included on the Unit Information List. It is produced through consideration of weight and size of each unit, taking into consideration the capabilities of each process gate. An example is provided as Figure 5-19.

IHI prepares formal Assembly Specifications Plans based on the information developed during the preliminary process planning stage. These plans detail the methods to be followed during fabrication, assembly and erection.

Preliminary Assembly Specification Plans are prepared for units of the fore and aft sections of the ship and for typical midship sections. An evaluation of the assembly sequence determines the proper assembly process lanes to be used. Figure 5-20 is an example of a Preliminary Assembly Specification Plan.

5.4 DETAIL PROCEDURES

The purpose of specifying detail procedures is to establish efficient, uniform, sequential patterns of work plans for field personnel to follow. These procedures aid in job preparation by stipulating in advance the necessary materials, equipment, jigs and components that will be needed. These guidelines assist foremen and improve the working environment in the following ways:

1) Establishes a pre-determined standard method of operation.

2) Prescribes the most effective sequence of activities.

3) Specifies arrangement and uses of necessary jigs and fixtures.

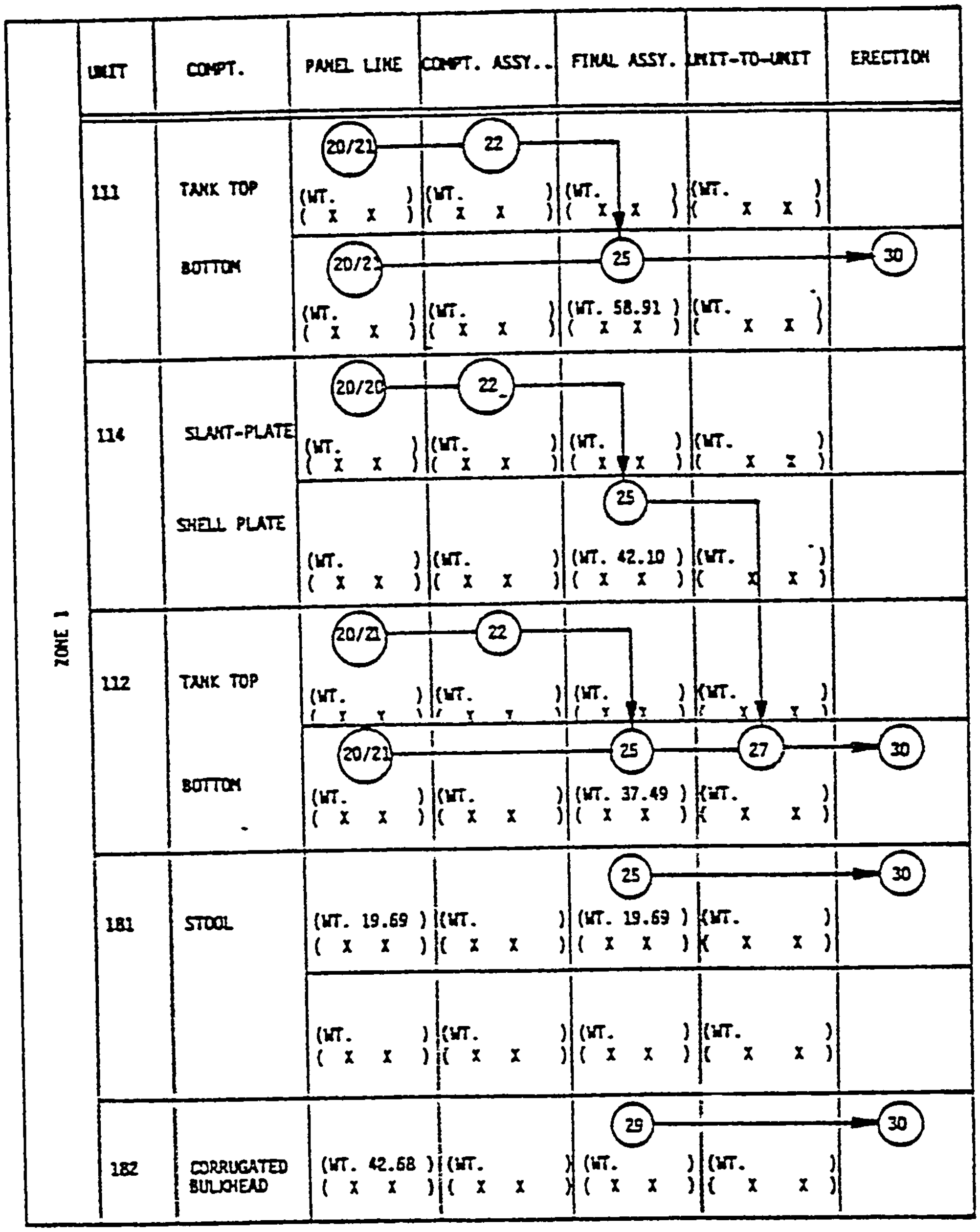
ZONE	PART	UNIT	WT.	SIZE	DESCRIPT	GATE	PROCESS FLOW	DAYS HOURS	START DAY	ERECTION DATE
ZONE 4	BOTTOM WING TANK UNITS	Side Shell & Bilge Unit 114 164		12'-5'2 36'-9	Bilge Curved Unit		115 165 (Inland)	2 days 8		
		Side Double Bottom 112-162	50.98 x 6		Bilge Part Unit	22	115 165 (Inland)	7 days 96		
		River Side		17' 36'9	Hopper Slope Panel	20 or 21	115-165 (Inland)	3 days 24		
					Unit	22	115 165 (Inland)	6 days 68		
				25'-9 36'-9	Final Assy	25	Shell Base (Hopper Slope)	2 days 18		
			91.62 x 10	33'-6 36'-9	Unit to Unit	29	Side Double Bottom x Bilge Base	9 days 160		
		Side Shell & Bilge unit (104 & 174) X Side Double Bottom (102 & 172)	53.04 Tank X 2 Units	12'5-1/2 36'-9	Bilge Part Unit	22	Inland Side (115-165)	7 days 96		
					Hopper Slope Panel	20 or 21	Inland Side (115-165)	3 days 24		
				17-8 36-9	Hopper Slope Unit	22	Inland Side (115-165)	...		
					Final Assy.	25	(Shell Base) x (Bilge Part) x (Hopper Slope)	8 days		

CODE:

S.A.W. - Submerged Arc Welding
L - Layout
B - Burning
AR - Arranging
F - Fitting
W - Welding
Ins - Unit Inspection
OF - Outfitting
P - Painting
T/O - Turnover

UNIT INFORMATION LIST

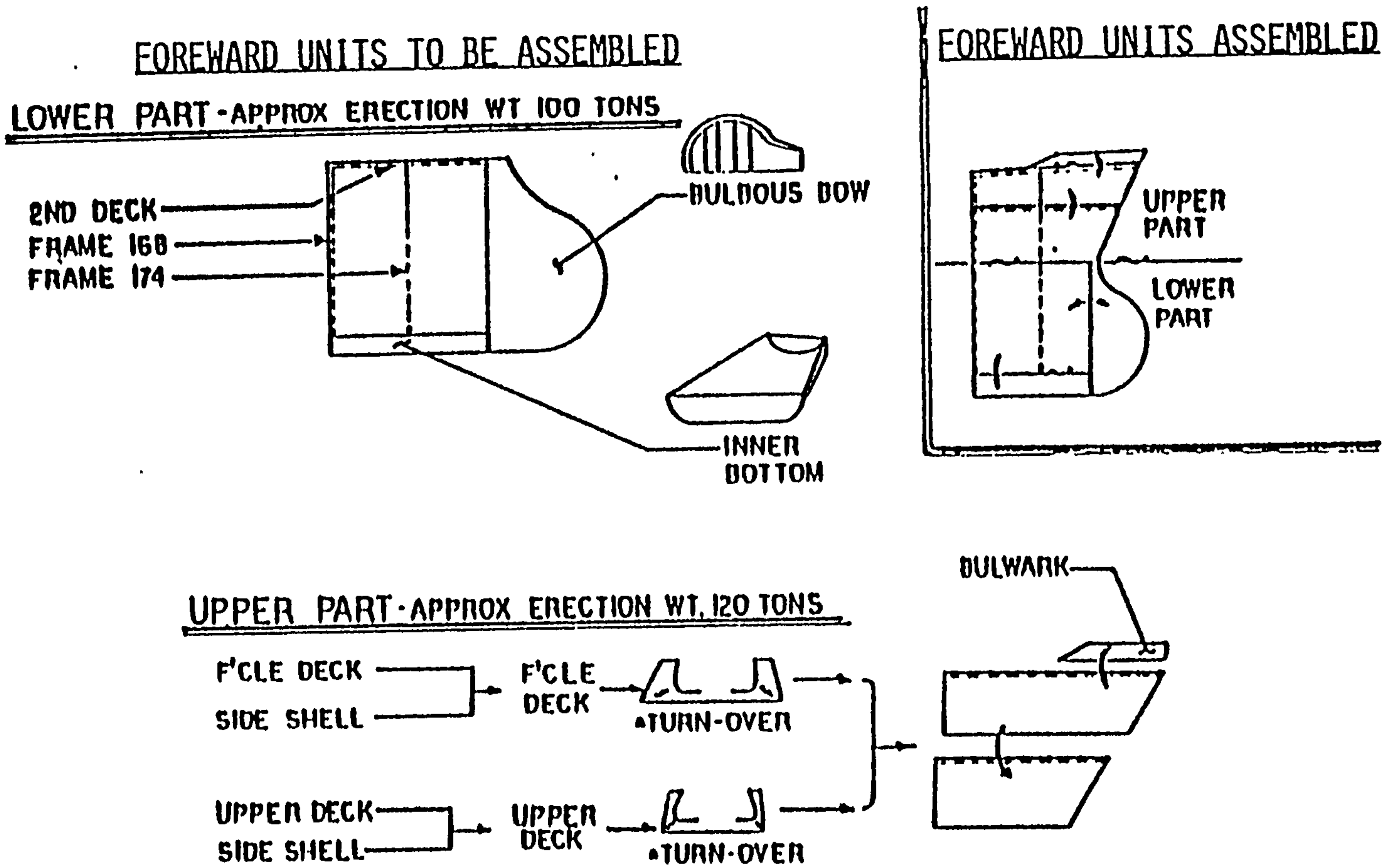
FIGURE 5-18



BASIC PRODUCTION FLOW LIST

FIGURE 5-19

NOTE: Unit dimensions are specified in brackets i.e. (L x W x H)



NOTE: THESE UNITS TO BE ASSEMBLED AS CONDITIONS PERMIT AT THE PRE-ERECTION STAGE.

PRELIMINARY ASSEMBLY SPECIFICATION PLAN

FIGURE 5-20

4) Issues warning notes to exercise care in the work being done in order to avoid a future problem.

5) Provides consistency between foremen, between shifts, between departments, etc.

6) Designates details of work within a specific area and its relationship to other supporting work.

7) Gives a broad overview of the total scope of work for better understanding of each individual segment.

The main emphasis on development of process standards in the Technology Transfer Program was placed on the assembly and sub-assembly areas. The detail assembly procedures are specified at IHI by the staff engineer and issued to production foremen. They are intended as guidelines for assembly of units of similar construction. However, the procedures are followed strictly as issued except for individual differences in the structural assembly itself.

IHI submitted to Livingston assembly procedures and guidelines for some typical units on the F-32 bulker. An example of a typical assembly procedure for an innerbottom unit prepared by IHI is presented in Figure F-21. These assembly procedures and guidelines typically include the following elements:

1) Sketches of the unit as it is progressively constructed from 2-dimensional panels to 3-dimensional assembly units.

2) Identification of pieces shown on the sketches.

3) Critical dimensions where accuracy is critical.

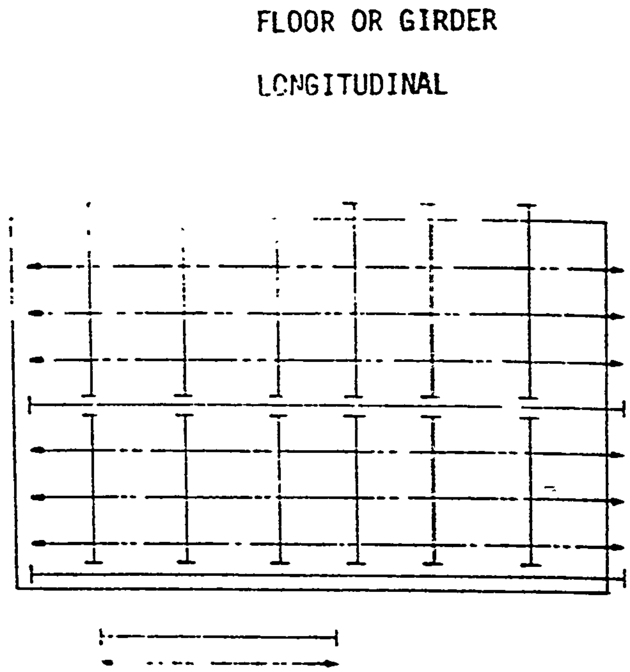
4) Detailed instructions on the proper assembly method.

5) Sequence of assembly in numbered steps.

6) Specifications and use of required jigs, tools, and measuring instruments.

7) Notes of potential problems and how to avoid them.

TYPICAL INNERBOTTOM UNIT



1. Fit and weld all structurals on the tank top panel at the panel line.
2. Set the tank top panel on a flat slab.
3. Set jigs in the arrangement shown below:

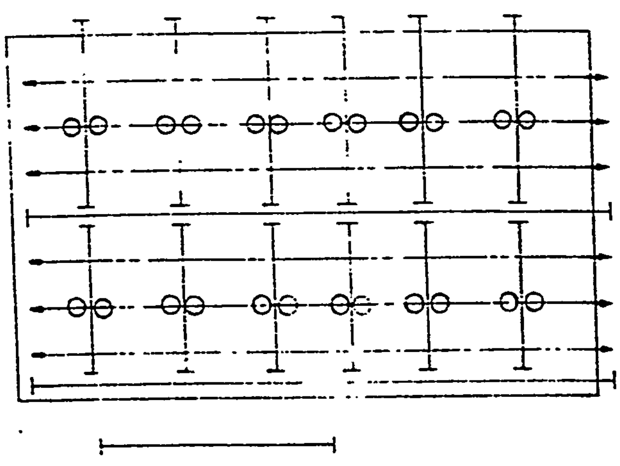
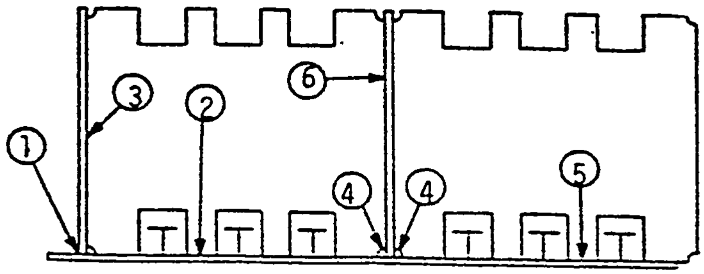
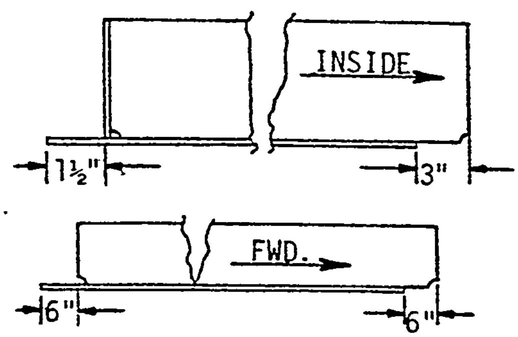


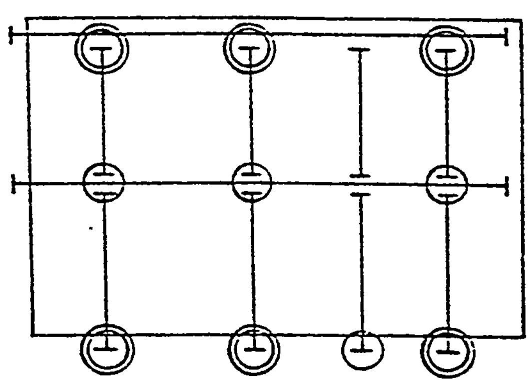
FIGURE 5-21

4. Fit floors and girders on the panel in sequence 1 to 6





Check level before fitting



5. Weld as specified.

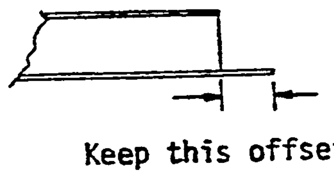
LEGEND:

◎: Checking points

○ : Fixed points

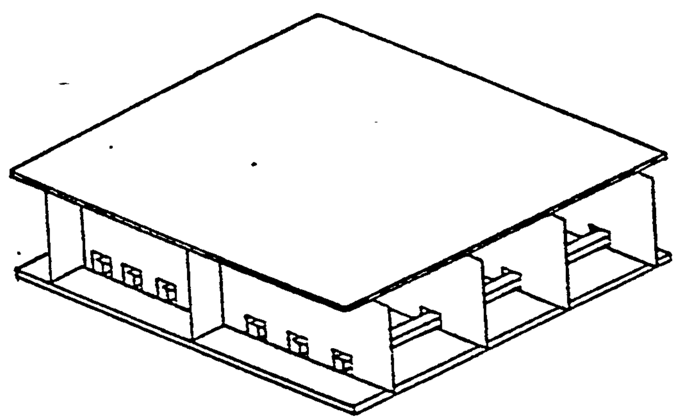
FIGURE 5-21 (Cont.)

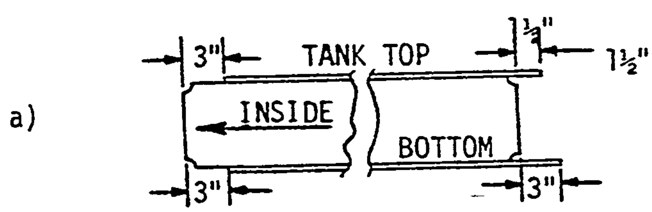
6. Fit and weld all structurals on the bottom panel.

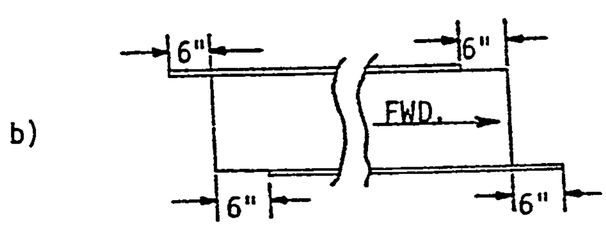


7. Turn the tank top over and place it on the bottom panel.

8. Fit as specified.







After checking level, square up panel using fixed stops.

9. Weld as specified.

FIGURE 5-21 (Cont.)

8) Identification of the unit by name, where applicable, and of adjacent units where this provides clarification.

Similar procedures were provided by IHI for outfitting guidelines. An example of these procedures is provided as Figure 5-22. The primary objective of these procedures involving outfitting is to Maximize the pre-outfitting at assembly (rather than erection) stages, to simplify the procedures, to specify the sequence providing the best working environment and most accessible positions for the job, and to prevent interferences from occurring later. The 3-dimensional sketches are excellent aids in providing a conceptual visualization of the unit as it will look when outfitting is completed.

5.5 DETAIL TIME STANDARDS

The IHI engineer’s familiarit!y with the daily operations within his area permits him to easily set detailed time standards. Traditional time and motion study techniques are used to develop standards for a routine, repetitive operation. Figure 5-23 is a process standard written by IHI for the panel joining process as observed at Livingston’s panel line. Each element is listed in sequential order with the number of workers and time required to perform each element. The format of this time study illustrates the IHI engineers’ portrayal of an operation with visual aids such as the “clock” time, the sketch of the panel and the slanting time frame.

The efficiency for this operation is calculated by the formula:

EFFICIENCY = WELD LENGTH ÷ (NO WORKERS) X (TOTAL TIME REQUIRED)

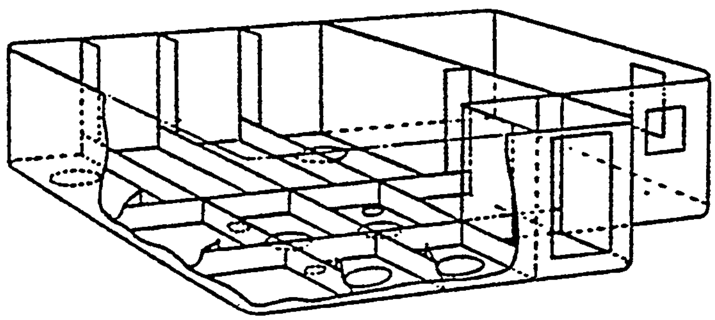
5.6 LEVINGSTON APPLICATIONS

At the outset of the Technology Transfer Program (TTP) Livingston kept few records and issued no formal instructions, procedures, or work manuals of the types maintained at IHI. The best documented methods that could be

STACK HOUSE

(ON SLAB)

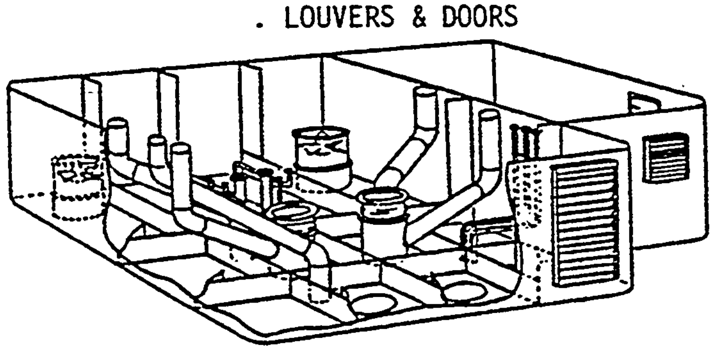
1. COMPLETE STEEL UNIT ASSEMBLY



2. INSTALL FITTINGS - FIG. 6

OUTFITTING IS DONE ON STACK HOUSE UNIT WHICH IS BEING SITUATED ON SLAB UP SIDE DOWN.

FITTINGS
. VENTILATION TRUNKS AND FANS
. BOILER INCINERATOR EXHAUST PIPES
. MAIN ENGINE EXHAUST GAS BY-PASS PIPES
. SUPPLY AIR TRUNKS TO MAIN ENGINES
. ORDINARY PIPES
. LOUVERS & DOORS



NOTE: THOUGH MAIN ENGINE EXHAUST GAS PIPES, WITH EXPANSION JOINTS ON THEM, ARE SKETCHED, THEY SHOULD BE INSTALLED ON-BOARD.

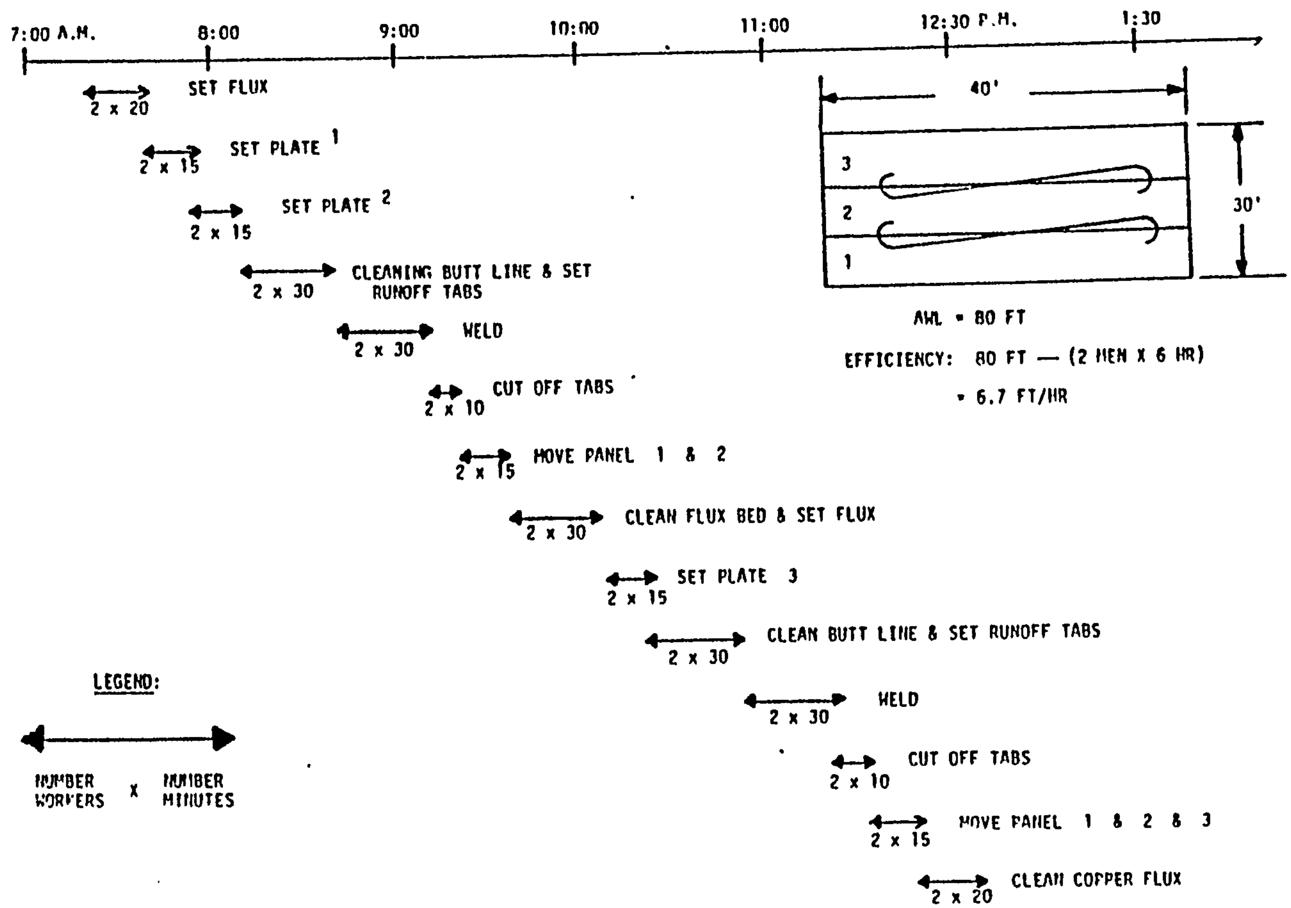
3. PAINT

4. TURN OVER

5. ERECT

TYPICAL ASSEMBLY PROCEDURES - OUTFITTING

FIGURE 5-22



PANEL JOINING PROCESS STANDARD

FIGURE 5-23

considered process standards were those issued by the Welding Engineer. Since inception of the TTP, the following improvements have been implemented or are being considered at Livingston toward development of Process standards:

1) Designation and implementation of the “process lane” concept, termed the “gate system”.

2) Issuance of formal Assembly Procedures and Guidelines for each hull under construction.

3) Work manuals will be prepared for issue to each gate or group of gates.

4) Information for handbooks for craftsmen is being organized.

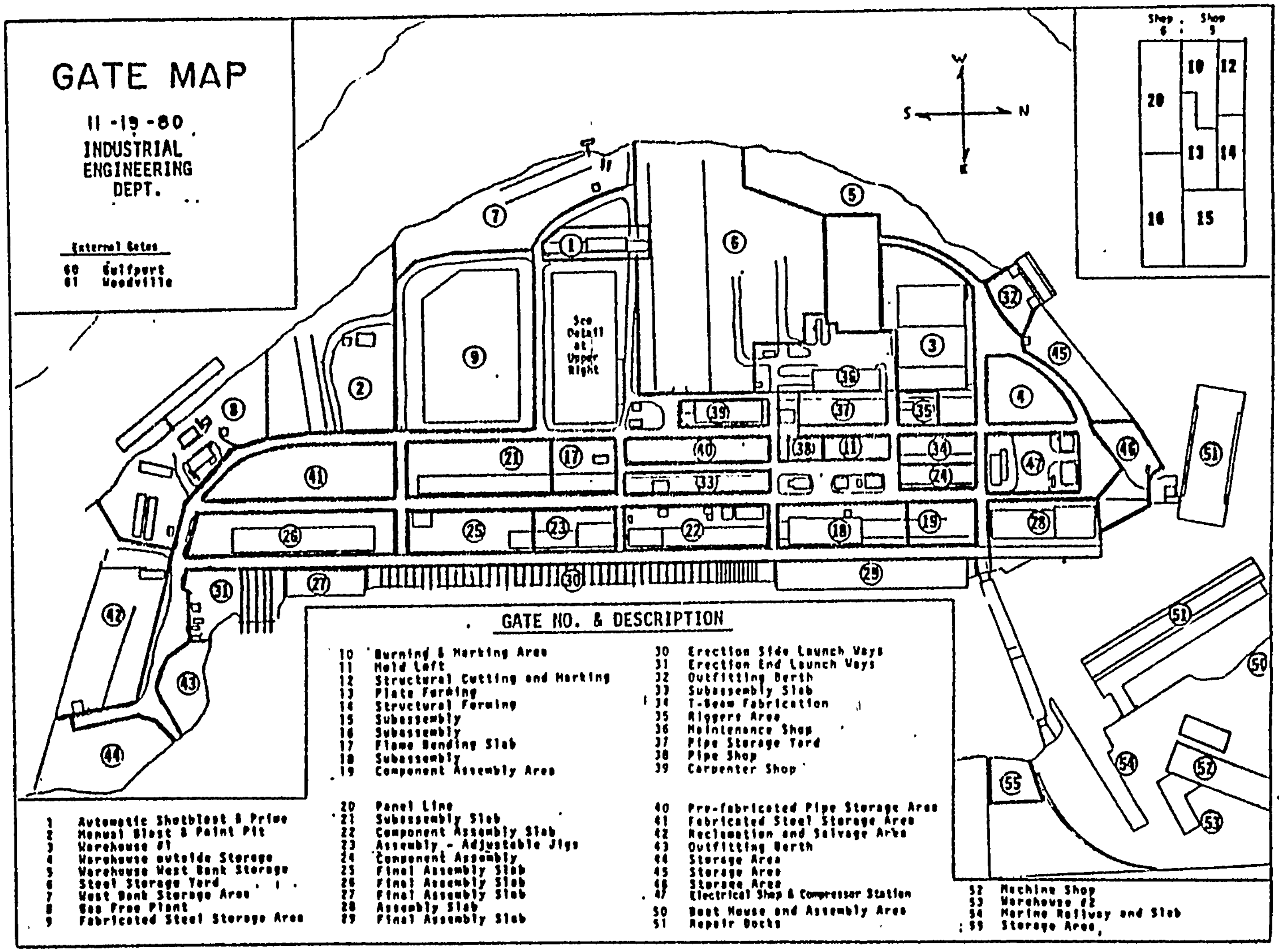
A. GATE SYSTEM

A thorough description of the “gate system” and the status of implementation of this concept at Livingston is provided in the TTP Final Report on Planning and Production Control. In this report, the concept of the gate system was described as the assignment of an area(s) for specific types of work or processes; the assignment of a group of workers together with a foreman to a permanent area that processes the same type of work regularly, so that planning and scheduling becomes standardized and routine. In the context of this description, the following changes have been adopted:

1) Assignment of gate numbers and descriptions to specified locations within the facility (Figure 5-24).

2) Assignment of Production Supervision, Production Control personnel (Area Coordinators) and Material Control personnel to certain “gates” of responsibility (Figure 5-25). It is also being considered to carry this step to the Industrial Engineering group through assignment of Area Engineers to gate responsibility.

3) Division of the planning, scheduling, and manning control systems to reflect the changes made to implement the gate system concept (Figure 5-26).



GATE MAP
11-19-80
INDUSTRIAL ENGINEERING DEPT.
External Gates
60 Gulfport
61 Woodville
See Detail at Upper Right
Shop 6
Shop 5
GATE NO. & DESCRIPTION
1 Automatic Shotblast & Prime
2 Manual Blast & Paint Pit
3 Warehouse #1
4 Warehouse outside Storage
5 Warehouse West Bank Storage
6 Steel Storage Yard
7 West Bank Storage Area
8 Gas Free Plant
9 Fabricated Steel Storage Area
10 Burning & Marking Area
11 Mold Loft
12 Structural Cutting and Marking
13 Plate Forming
14 Structural Forming
15 Subassembly
16 Subassembly
17 Flame Bending Slab
18 Subassembly
19 Component Assembly Area
20 Panel Line
21 Subassembly Slab
22 Component Assembly Slab
23 Assembly - Adjustable Jigs
24 Component Assembly
25 Final Assembly Slab
26 Final Assembly Slab
27 Final Assembly Slab
28 Assembly Slab
29 Final Assembly Slab
30 Erection Side Launch Ways
31 Erection End Launch Ways
32 Outfitting Berth
33 Subassembly Slab
34 T-Beam Fabrication
35 Riggers Area
36 Maintenance Shop
37 Pipe Storage Yard
38 Pipe Shop
39 Carpenter Shop
40 Pre-fabricated Pipe Storage Area
41 Fabricated Steel Storage Area
42 Reclamation and Salvage Area
43 Outfitting Berth
44 Storage Area
45 Storage Area
46 Storage Area
47 Electrical Shop & Compressor Station
50 Boat House and Assembly Area
51 Repair Docks
52 Machine Shop
53 Warehouse #2
54 Marine Railway and Slab
55 Storage Area,

FIGURE 5-24

AREA COORDINATORS

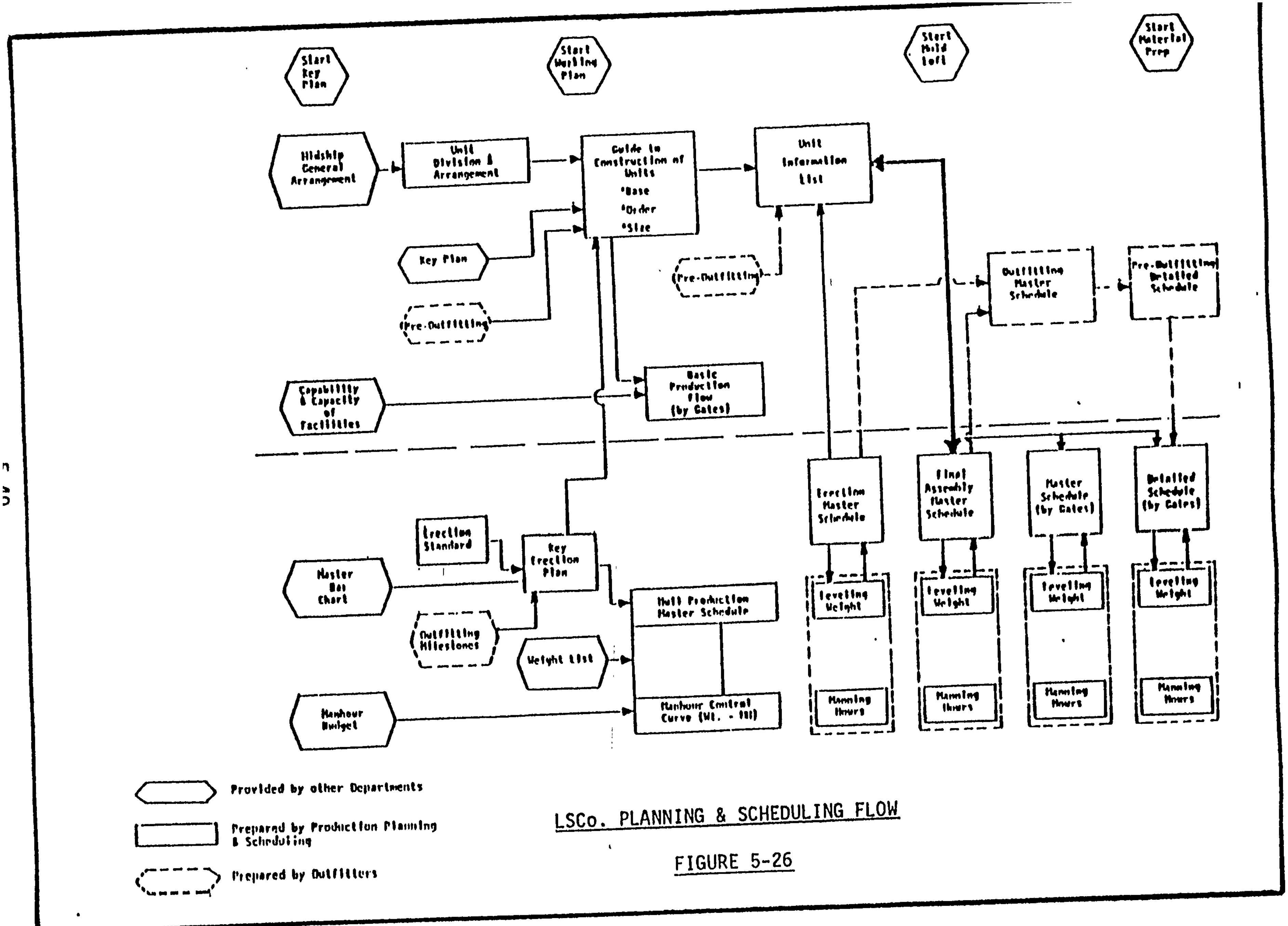
1	Jimmy Fontenot Ext. 427
Gate #	**Foreman (D)**
1	David Byrd (2)
2	Carey Gruber (2)
10	John Fuqua (5)
12	John Fuqua (5)
13	Bill Granger (5) J. W. Smith (6)
14	Bill Granger (5) J. W. Smith (6)
15	Bill Granger (5) J. W. Smith (6)
20	Bill Shields (6)

2	Jean Harris Ext. 424
Gate #	**Foreman (D)**
17	Bill Granger (5) J. W. Smith (6)
21	Jake Thornton (5) J. W. Smith (6)
26	J. D. McDonald (4) John McWilliams (6)
27	Ojust Clements (4) Jimmy Boyd (6)
31	Pete Holmes (4) Darrell Laughlin (4) Sparky Ballia (4) Russell Frederick (6) John Says (6)

3A	Charles DuChamp Ext. 416
Gate #	**Foreman (D)**
22	W. W. Arras (4) Jimmy Boyd (6)
23	W. W. Arras (4) Jimmy Boyd (6)
25	O. J. Clements (4) Jimmy Boyd (6)
30	Pete Gauthier (4) John Doucet (4) Bill Gearen (6)

3B	Murphy Burch Ext. 413
Gate #	**Foreman (D)**
18	G. L. Cribb (5) C. B. Duhoh (6)
19	G. L. Cribb (5) T. B. Guinn (5) C. B. Duhon (6)
24	W. R. Brady (4) J. L. Landry (5) C. B. Duhon (6) H. Levier (6)
28	W. R. Brady (4) J. L. Landry (5) H. Levier (6)
29	O. J. Broussard (4) T. B. Guinn (5) M. Myers (6) C. B. Duhon (6)
34	J. L. Landry (5) H. Levier (6)

FIGURE 5-25



LSCo. PLANNING & SCHEDULING FLOW

FIGURE 5-26

B. ASSEMBLY PROCEDURES AND GUIDELINES

Formal procedures of specified assembly plans have been written by Industrial Engineering and issued to the production Departments . These procedures have been issued for each hull under construction since the first bulker (in-eluding duplication for like hulls). The procedures specify the assembly methods for each typical unit in the hull, complete with sketches, detailed instructions, sequence of steps, crucial dimensions, arrangements of the unit with jigs, and other necessary information. An example of a typical Assembly Procedure and Guideline issued for the construction of the bulker is given as Figure 5-27.

This procedure has been welcomed by the Production Department as an effective aid to promte uniform methods and procedures, to visualize the assembly process, to help avoid problems in assembly and accuracy control, and to plan their work. The value of these guidelines has resulted in extension of this technique into drilling rig construction planning. It is planned-to expand the issuance of these procedures beyond assembly stages into the Fabrication, Sub-Assembly and Erection stages of hull construction, as well as the pre-outfitting stage in outfitting.

C. WORK MANUALS

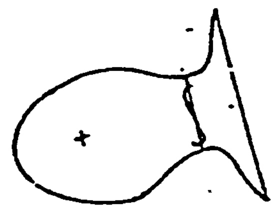
It is Livingston’s plan to issue work manuals for each gate or set of related gates. These work manuals are visualized to contain such information as working procedures, gate layout, material flow, data collection, forms, statistical reports and charts generated, quality standards, safety precautions, manpower assigmnents, and ,the like.

These work manuals are foreseen to be a product of Industrial Engineering for use by Production Supervision. The concept of issuing these manuals in

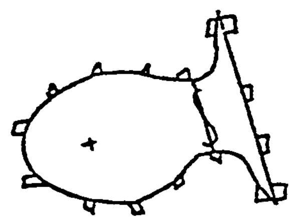
TYPICAL CONSTRUCTION ASSEMBLY SKETCH

LSCo ASSEMBLY PROCEDURES AND GUIDELINES FOR UNIT 241

1. FIT AND WELD FR. 10 PLATE (BOTH SIDES) ON FLAT SLAB.



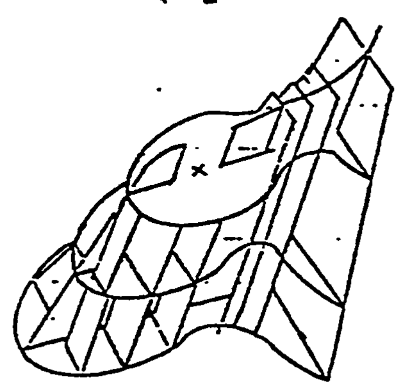
2. SET NECESSARY SUPPORTS AT LEAST 10" HIGH. SET FR. 10 PLATE ON SUPPORTS.



3. SET AND FIT STRUCTURALS, FLAT AND FRAMING ON FR. 10 PLATE.

   WELD INTERNALS.

4. PUT CASTING ON.



5. PUT SHELL PLATE ON IN SEQUENCE OF A-B-C-D-E-F AND FINISH WELDING.

   PUT SHELL PLATES G-H-I-J ON AND FINISH WELDING.

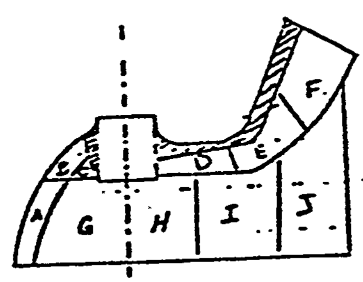


FIGURE 5-27

this manner can be attributed to IHI suggestions in the TTP; however, specific contents of such a manual would be unique to each shipyard.

As mentioned earlier, past documentation at Livingston has been predominately in the welding field. Process standards, or standard procedures, as issued in their current form at Livingston contain guidelines for welders to follow. The specified welding parameters such as speed, amps, volts, etc may be varied at each welder's discretion as conditions warrant. This allowance is in contrast to IHI's insistence that their welders adhere strictly to specified welding parameters. While conceding this IHI practice is preferable for producing consistently good quality work, it is not in Livingston's current plans to provide field engineer to issue such precise instructional material at this time. However, this is a distinct possibility for the future. Livingston does plan to continue issuing Welding Procedure Specifications which are based on the Procedure Qualification Record approved by ABS. These instructions specify the type material, position, electrodes., etc. qualified for a specific procedure as discussed in tie welding Methods section of the TTP Final Report on Facilities and Industrial Engineering.

D. CRAFT HANDBOOKS

Another desirable form of standards document is a handbook for each craft. IHI issues handbooks to each worker specifying guidelines to follow in the performance of his work. These handbooks contain both general and specific guidelines concerning such subjects as work tools, job procedures, safety precautions, quality standards, etc.

The writing and issuing of these types of handbooks are not foreseen in the near future for Livingston but are prospective goals. Information for welders' use is currently being generated that would be included in this type of handbook.

5.7 CONCLUSION

The concept of process standards is not new to U.S. industry nor unique to Japanese industry. The amount of application of standardization of processes, however, and particularly the documentation of these standards is much more prevalent at IHI than it has been at Livingston.

IHI's approach to process standards emphasizes group technology and organized, thorough documentation. The concept of group technology affects process standards through the efforts to tie the standardization of products (units in a ship, palletization, etc.) to the standardization of processes and facilities (gate system concept, pre-outfitting, etc).

The concepts discussed in this section are certainly applicable to any shipyard. As discussed in the Planning and Production Control Final Report, however, maximum benefits can only be achieved through adoption of the total system. An effective process standards program requires integration of materials, facilities, and manpower with standardized operations and procedures. To adopt the IHI system piecemeal would consequently reduce its total effectiveness in improving productivity.

The main points stressed by IHI and hereby confirmed as necessary ingredients in an effective process standards system are:

1) Implementation of a unitization concept whereby a whole can be divided into component parts.

2) Development of uniform, standardized methods for simplification and repetition purposes.

3) Thorough documentation of processes and procedures.

4) Good corrrnunication practices.

5) Implementation of effective feedback systems.

SECTION 6

COST STANDARDS

6.1 INTRODUCTION

One of the most impressive aspects of the IHI production system is the remarkable adherence to schedule. This phenomenon was immediately visible to the Livingston team members visiting the IHI shipyards, and an observation on which they all commented. The development of such precise scheduling techniques comes as no accident or coincidence. It is the result of carefully planned, thoroughly documented information systems which are devised to develop standard data. The process standards discussed in the foregoing section specify the proper methods to be followed which result in procedural standardization. The subsequent step is the measurement of performance resulting from application of these process standards, amounting to standardized units of time per product, or numbers of product per time element, which are the basis for cost standards.

IHI's analysis of the Livingston system of planning and scheduling led them to the following observations:

1) Schedules based on tonnage as the only parameter are inaccurate; there is usually no direct relationship between weight of work and manhours required to perform the work.

2) The system did not lend itself to easy or accurate determination of the actual status of work in progress.

3) Frequent changes in priority unfavorably influence the relationship between planning and field personnel.

4) Poor communication and lack of confidence existed between planning and field personnel.

5) Lack of communication existed between fitting and welding departments.

6) Information supplied to the field on construction plans was inadequate.

The system proposed by lHI to Livingston for improved planning and scheduling results was discussed in the Process Standards section. The types of records to be used to establish this system were illustrated in that section. In conjunction with establishment of standardized work procedures, or process standards, a measurement system of the rate of production results in performance standards. These standards form the basis of cost standards, which are defined in this report as:

A cost standard is a measured rate of production for a given process to be used in planning, scheduling and estimating activities and in calculating the cost of the process.

Examples of cost standards in the shipbuilding process include: manhours per ton, inches per minute (cutting), feet per hour (welding), etc. These figures would have to be extended by an individual shipyard to its own calculated costs for each process. The' distinction between cost standards and process standards, and the resulting overlap of terms, was also explained in the Process Standards section of this report. In this explanation, it was noted that IHI documents and charts often use the term "process standard" in a manner that would comprise both "process standards" and "cost standards" as described in this report.

6.2 DOCUMENTS

There are a number of status reports reconnnended by IHI for use in the development and application of cost standards. Explanation of the use of these forms follows later in this section of this report. A brief description of the forms is provided here as preface to those explanations:

1) Manhour Collection Sheets

   a) Daily record of manhours spent on each unit, by worker name. (See Figure 6-1)

   b) Monthly record, composed of summation of data on daily records. (See Figure 6-2)

2) Efficiency Records on productivity, e.g., meters/hour ratio on welding. (See Figure 6-3)

3) Blackboards--Displays posted in designated areas specifying schedules, productivity, quality of work, etc. (See Figure 6-4)

6.3 DEVELOPMENT OF COST STANDARDS

The purpose for developing process standards and cost standards from the IHI viewpoint is for use in the following applications:

1) Base data for estimating manhour requirements

2) Base data for estimating periods of completion for jobs

3) Base data used toward determining needed improvements in equipment and facilities

4) Base data used in status reporting and applied toward improving productivity

5) Educational material and training aids for field personnel

The data used to calculate cost standards are derived from the previously developed process standards. The approach recmnded by IHI for the determination of process standards first involves classification of the elements to study. The basic elements regarding hull construction are listed in Table T6-1. For each of these elements, such as marking, cutting, bending, etc., the factors which chiefly influence the process standards are specified. This includes such items as the method employed, equipment used, environmental conditions (inside ships, outside, cramped quarters, positioning of worker and workpiece, etc.) and similar influencing factors.

GATE ______ FOREMAN ______________________ SHIFT ______________

WORKER / UNIT	I.K.	B.T.	E.F.	T.R.	S.S.	H.K.	C.L.	R.M.					
101	8	8	8	8	8	4	4	4					52^H
111						4	4	4					12^H

FOREMAN ______________________ SHIFT ______________

WORKER / UNIT	I.K.	B.T.	E.F.	T.R.	S.S.	H.K.	C.L.	R.M.					
101	8	8	8	8	8								40^H
111						8	8	8					24^H

DAILY MANPOWER RECORD (SAMPLE)

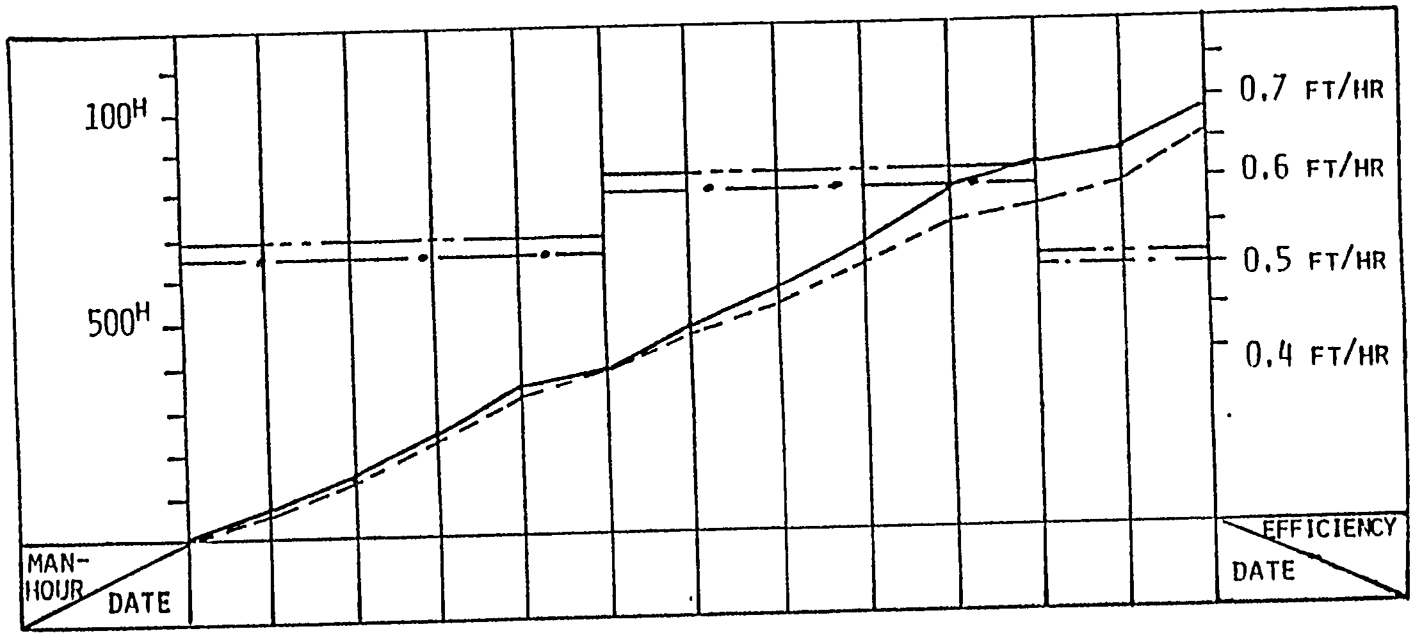
FIGURE 6-1

CRAFT: FITTERS

UNIT	W.L. (FT)	ISSUED MAN-HOURS	DAILY MANHOURS CHARGED																				TOTAL MAN-HOURS
			6/9	10	11	12	13	16	17	18	19	20	23	24	25	26	27	30	7/1	2	3	4	
101	470	115				16	16	32	32	32	16	16											128^H
111	520	125								16	16	32	32	32	16								144^H
121	485	120													16	32	32	32	24				136^H
131	490	120																	8	32	32	32	104^H

UNIT	W.L. (FT)	ISSUED MAN-HOURS	DAILY MANHOURS CHARGED																				TOTAL MAN-HOURS
			7/7	8	9	10	11	14	15	16	17	18	21	22	23	24	25	28	29	30	31	8/1	
131	490	120^H	16																				120^H
141	465	115^H	16	32	32	16	16	16															128^H
151	515	125^H				16	16	16	32	32	16												128^H
161	510	120^H									16	32	32	32	16	16							144^H
171	495	120^H													16	16	32	16	16				128^H

FIGURE 6-2 MONTHLY REOCRD OF MANHOURS (SAMPLE)



LEGEND

AVERAGE (ACTUAL)

AVERAGE (GOAL)

CUMULATIVE (ACTUAL)

CUMULATIVE (GOAL)

EFFICIENCY CHART

FIGURE 6-3

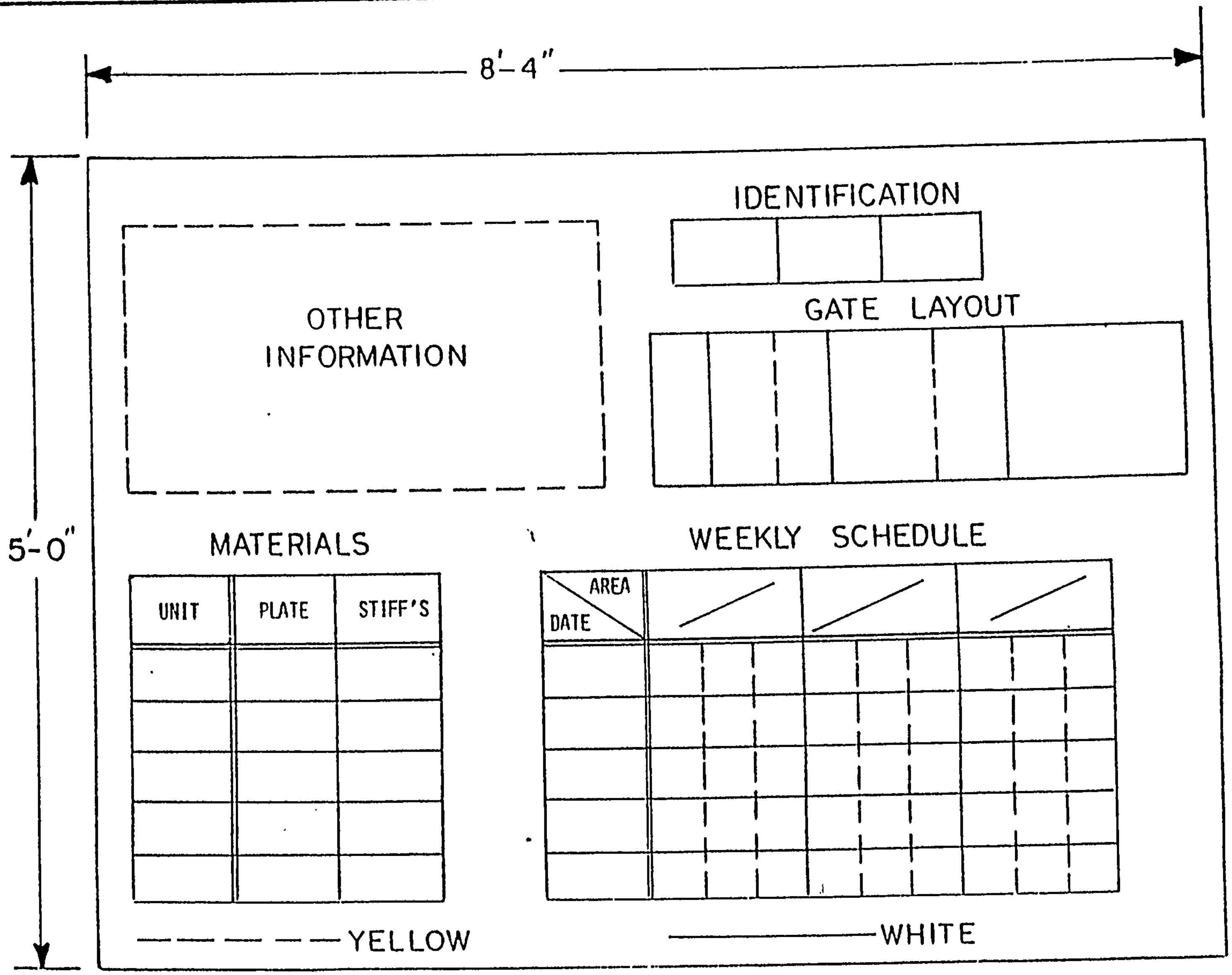


FIGURE 6-4 DESCRIPTION OF BLACKBOARD (SAMPLE)

TABLE T6-1

PROCESS STANDARD ELEMENTS

ELEMENTS	EXPLANATION/EXAMPLES	INFLUENCING FACTORS
A. Material Handling	Raw materials, pieces, sub-assemblies, assembled units, etc.	1. Method of transportation 2. Equipment options 3. Frequency 4. Distance
B. Marking	N/C, Flame Planer, Manual at Fabrication, Assembly, Erection	1. Method 2. Environment 3. Marking length
C. Cutting	N/C, Flame Planer, Manual at Fabrication, Assembly, Erection	1. Method 2. Instrument 3. Environment 4. Plate thickness 5. Cutting length 6. Type of bevel
D. Bending	Plate, Structural, Bracket, Face Plate, etc.	1. Method 2. Thickness 3. Amount of Curvature
E. Fitting	At Fabrication, Assembly, Erection	1. Method 2. Environment 3. Fitting length 4. Gap
F. Welding	At Fabrication, Assembly, Erection	1. Method 2. Environment 3. Leg length 4. Material quality 5. Welding length
G. Finishing	At Fabrication, Assembly, Erection	1. Method 2. Environment 3. No. of temp. pieces 4. Material quality
H. Painting	At Fabrication, Assembly, Erection	1. Method 2. Environment 3. Area Painted 4. Type of Coating

By studying and analyzing these basic elements of the shipbuilding cycle, a shipyard can determine the control parameters it may best utilize for each element. This can be determined by the data collected at the facility, the measurement technique it can best employ with the resources it has available, and the accuracy and applicability of the data measured. Table T6-2 specifies the measuremnent parameters used at IHI for each working stage. Also included in this table are the efficiency factors achieved at IHI and the parameters recommended for application at Levingston. These parameters are used to measure the performance factors that become the established cost standards.

IHI applies welding length extensively as a parameter for process standards. Livingston has historically maintained records in the form of weight (tonnage) processed, and has applied ratios of manhours of tonnage. IHI believes welding length has a more significant relationship to the amount of work required both in fitting and welding than does tonnage. According to IHI, this reliance on tonnage figures for manpower planning at Livingston is the greatest contributor to the disparity between projected and actual manhour figures in detail planning. In the case of long-term scheduling or rough manhour estimating, tonnage figures are considered acceptable parameters.

IHI acknowledges that figures on tonnage are easier to obtain and generally more accessible information. Therefore, two methods of obtaining welding lengths are described:

1) Use of conversion ratios from weight to welding length, according to location of a unit within the ship.

2) Detailed measurement of actual welding lengths.

TABLE T6-2

CONTROL PARAMETERS

SHOP	STAGE	WORKING	PARAMETER (IHI)	EFFICIENCY (IHI)	RECOMMENDED PARAMETER (LSCO)
FABRICATION	MARKING & CUTTING	EPM	NUMBER of plate	0.5 H/PL	NUMBER
		FLAME PLANER	"	1.12 H/PL	
		CURVATURE CUTTING	"	2.85 H/PL	
		N/C CUTTING	"	4.66 H/PL	
		SKELETON MEMBER CUTTING	"	4.68 H/PL	
		ANGLE CUTTING	"	0.69 H/PC	
		DECK HOUSE CUTTING	"	6.22 H/PL	
		SUB TOTAL	TONNAGE	1.43 H/T	TONNAGE
	BENDING	ANGLE BENDING	NUMBER of piece	1.5 H/P	NUMBER
		PLATE BENDING	" of plate	7.7 H/PL	
		SMALL PIECE BENDING	" of piece		
	SUB. ASSEM.	FITTING	W.L.	6.2 M/H	NUMBER
		WELDING	W.L.	5.4 M/H	"
		MATERIAL SORTING	TONNAGE	0.5 H/T	TONNAGE
		SUB TOTAL	TONNAGE	8.95 H/T	"
	OTHERS	MATERIAL HANDLING	TONNAGE	0.23 H/T	TONNAGE
		SHOT BLASTING	NUMBER of plate	0.48 T/PL	NUMBER
		CRANE			
		T.TYPE LONGL.	NUMBER of piece	12.5 H/P	NUMBER
ASSEMBLY	EACH SHOP	PLATE JOINING	A.W.L.	1.84 M/H	A.W.L.
		FITTING	W.L.	7.68 M/H	W.L.
		WELDING	W.L.	3.46 M/H	W.L.
		FINISHING	W.L.	20.09 M/H	W.L.
		MATERIAL HANDLING	TONNAGE	0.65 H/T	TONNAGE
ERECTION	PRE.ERE. SKIN. SKELETON	FITTING	W.L.	2.77 M/H	W.L.
		WELDING	W.L.	0.91 M/H	W.L.
		FINISHING	W.L.	11.50 M/H	W.L.
OTHER JOB		SCAFFOLDING	TONNAGE		TONNAGE
		CRANE	"		
		TRANSPORTATION	"		

The former method can only be applied, however, where historical records of unit make-up and manhour records for previously built ships can be captured. The basic philosophy of this method is to apply previous data to present conditions where similarities exist. The value of standards (product, material, process and performance standards) to future planning needs becomes apparent in the application of this method for obtaining necessary information in an efficient manner. The latter method is time-consuming, but is quite accurate for obtaining this vital information. Each of these methods is described in detail later in this section.

6.4 CONTROL PARAMETERS

Table T6-2 reveals that IHI uses the following units of measurement as control parameters in their establishment standards:

- Number of plates
- Number of pieces
- Tonnage
- Welding Length (W.L.)
- Automatic Welding Length (A.W.L.)

IHI seeks to use a parameter that relates to the time involved for processing of material as the primary consideration. Their objective is to use the simplest method of measurement without sacrificing accuracy or reliability of the data that is generated.

In fabricating ships, the number of pieces processed (e.g., plates, angles, small pieces, etc.) is most commonly accounted for and related to hours required. Welding length is used on sub-assembly fitting and welding, while aggregate tonnage suffices when measuring material handling and sorting functions. At the assembly and erection stages, welding length is the predominant unit of measurement.

6.5 MEASUREMENT OF WELDING LENGTH

As mentioned earlier, there are two distinct methods utilized at IHI for the measurement of welding length. This length is determined by using either:

1) Conversion from unit weight
2) Measurement on drawings

The former method is a rough estimate based on weight and location of the piece. It is not sufficiently accurate to use in detail planning and scheduling of work within gates as performed by the Planning Department. The calculations in this method aremade by the Engineering Department.

The latter method is more exact and useful in detail planning and control. It requires measurements from key plan drawings and requires a considerably greater investment in time. IH1 estimates Livingston would expend approximately 100 to 120 hours to take the measurements on a vessel the size of the F-32.

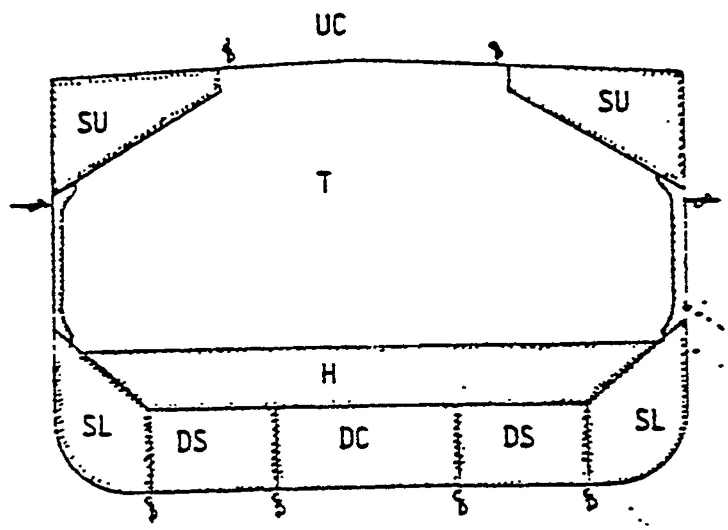
Each of these proposed methods of determining welding length is described below.

6.5.1 Conversion from Unit Weight

In this method, welding length is calculated from unit weights using the following formula:

WELDING LENGTH = WL (meters) = coefficient x Wt (tons)

This formula calculates total welding length without a distinction between one-sided (Iabelled as automatic) and two-sided welding. The coefficient values applied to the bulker are given in Figure 6-5.



COEFFICIENT:	ZONE 1	ZONE 2,3
DC (Double bottom center)	16.0	13.5
DS (Double bottom side)	15.0	13.5
SL (Side lower tank)	12.5	13.5
SU (Side upper tank)	13.0	14.0
UC (Upper Dk center)	16.5	26.5
T (Trans. Bhd.)	13.5 or 9.5*	-
H (Hopper)	25.5 or 20.5*	-
SF (Stern frame)	-	12.0
S.G.F. (Stearing gear flat)	-	15.0
Bol.Bow	-	17.5

* Determined by the bulkhead/hopper structure

BULKER DIFFICULTY COEFFICIENTS

FIGURE 6-5

The coefficients given in this chart apply only to the specific type of vessel illustrated. Another type, such as a tanker, container ship, or drilling rig would require the determination of coefficients for that particular vessel. However, where similarities exist between tk different types, the coefficient is transferable. As mentioned earlier, the determination of these coefficients is made from an examination of the historical records from previously built ships of the same type.

6.5.2 Measurement from Drawings

Where previous data are not available, or where very accurate figures are needed, welding lengths are taken from drawings. Briefly stated, typical measurements are made on key plans and extended from the scale of the drawing up to full scale. These measurements are applied across a ship section to obtain welding length for the total section. The reference drawings used in this method include:

Midship Section

Shell Expansion

Body Plan

Construction Plan

Construction Profile

The details of this method as it applies to the different sections of the ship are summarized below. In the determination of welding length for fillet welding or two-sided butt welding, the actual Iength measured on a drawing is doubled to obtain the total welding length.

FORE AND AFT SHELL

a. Longitudinal: Measure the average length of a longiitudinal, multiply it by the-number of Iongitudinals.

b. Web Frames: Same as for longitudinal.

W.L. = a + b + s

Where S = 35 to 45 meters

S is a safety allowance added in this case due to the size of brackets on the web frames.

FORE AND AFT CUBIC UNIT

a. Flat panel to floors, girders and longitudinal: Measure each line on the construction plan.

b. Shell to floor or longitudinal: Measure each line on the construction profile.

c. Floor to girders: Measure a typical height at each girder, multiply by number of floors at each girder.

d. Component to component: Measure the typical joint at a frame and longitudinal location, multiply it by the number of joints.

W.L. = a + b + c + d + s

Where S = 40 meters

ENGINE ROOM

a. Measure each line on the engine flat plan.

W.L. = a + S

Where S = 20 to 25 meters (the average amount of vertical welding length)

Includes the cooler flat, lower engine flat, upper engine flat, and upper deck panels.

ENGINE ROOM DOUBLE BOTTOM

a. Tank top to floors *or* to girders: Measure each line on the tank top plan.

b. Floors to girders: Measure a typical heightat each girder, multiply by the number of floors at each girder.

c. Bottom to floors: Measure one of the floors, multiply by the number of floors.

d. Bottom to girders: Measure each line on the shell expansion plan.

W.L. = a + b + c + d + S

S = 5 to 10 meters

HOLD PART

a. Panels (tank top, bottom shell, side shell, upper deck, slope) to floors: Measure a typical ring of the midship section.

b. Panels to girder and longitudinal: Measure length of the unit.

c. Floor to girder: Measure the height between the tank top and bottom shell, multiply by twice the number of "T" cross points.

W.L. = a x Number Floors + b x Number Girders and Longitudinal + c

6.6 ESTIMATING MANHOURS

6.6.1 Hull Construction

IHI uses combinations of techniques to estimate manhour requirements for an activity. The most common technique is use of historical data together with staff personnel experience to estimate manhours. On occasion, time study is used where historical data is not available, such as for a new process.

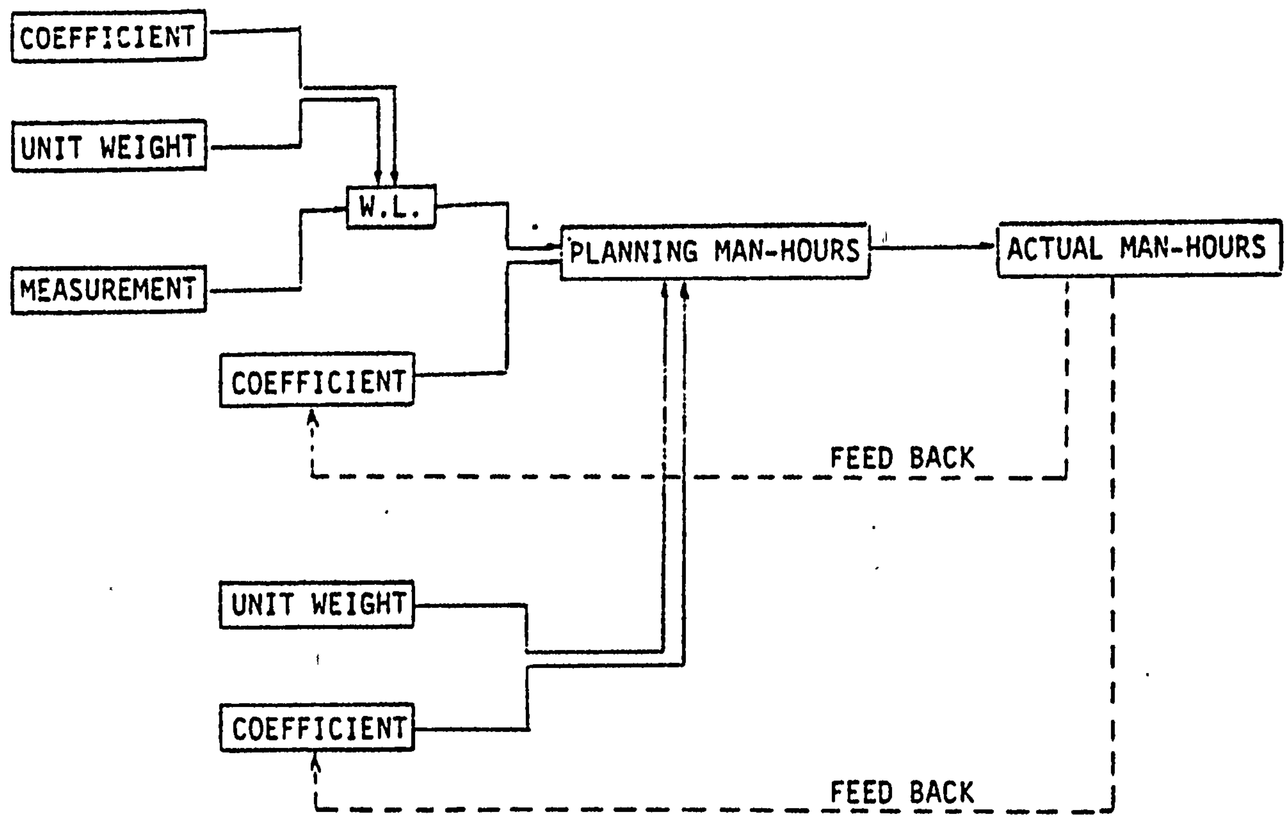
The forms described previously in the "Documents" portion of this section are used to collect data for this purpose. Manhour records maintained on timekeeping cards are compiled in the computer. From this data, manhour charges are collected and compiled by cost center. This data can then be retrieved to ascertain the manhours required on units previously built or similar ship types. Likewise, data collected and recorded on monthly records relate manhours used and spent on units containing the welding lengths that are specified.

1. Coefficients - Rough Estimates

For planning purposes, IHI uses records of actual manhours to calculate difficulty factors, or "coefficients", that are used to estimate future manhour requirements= These coefficients are used to convert unit weights to welding lengths, which is extended by formula to determine manhours. The correlation between actual manhours, coefficient factors, unit weights, welding lengths and planning manhours is illustrated schematically in Figure 6-6.

IHI is very methodical, meticulous and_precise in its data collection procedures. The Assistant Foreman (front-line supervisor) is aware of the future applications of the time charges of his workers and its importance and usefulness in the planning process. He is, therefore, careful to charge his workers' time accurately. The staff personnel work closely with the Assistant Foremen to organize data collection in meaningful terms and utilize the data in the development of process standards and determination of ship schedules. The Assistant Foreman sees the result of good timekeeping when he receives realistic and achievable schedules.

As mentioned earlier, IHI relies heavily on welding length as a control parameter used in developing process standards for hull construction. The two detailed method: of converting welding length to manhour estimations through the use of coefficients are each based on the accuracy desired. The procedures described below relate to determination of manhours in the assembly procedures,



ESTIMATION OF MANHOURS AT ASSEMBLY STAGE

FIGURE 6-6

including panel line, component assembly and final assembly because of emphasis placed in this area in the study of schedules.

To estimate manhours in broad terms, the following formula is applied:

H (manhours) = W.L. (weld length, meters) + coefficient (meters/hr)

The coefficient applied in this formula was determined by IHI engineers utilizing their technical experience and their thorough knowledge of the fitting and welding process. The coefficient applied to a given type of ship would vary at individual shipyards, but the basic tendency to stabilize to a reliable rate is prevalent inmost cases. The use of these figures again emphasizes the importance of accurate reporting of time charges.

The coefficients calculated by IHI for application by Livingston to the F-32 bulker are provided in pictorial form on Figure 6-7. These coefficients were determined by IHI using similar data which applies to their shipyard, and estimating Livingston efficiency on a ratio comparison to IHI efficiency (roughly 1:3). This ratio is based on IHI's observations of Livingston operations in construction of the F-32 type bulk carrier.

The chart visually displays the efficiency coefficient for fitting and welding based on location of the assembly unit within the ship. For example, in..the center double bottom where assembly work is comparatively easy, the coefficients given are:

Fitting = 3.1 m/h (meters/hour)

Welding = 2.7m/h (meters/hour)

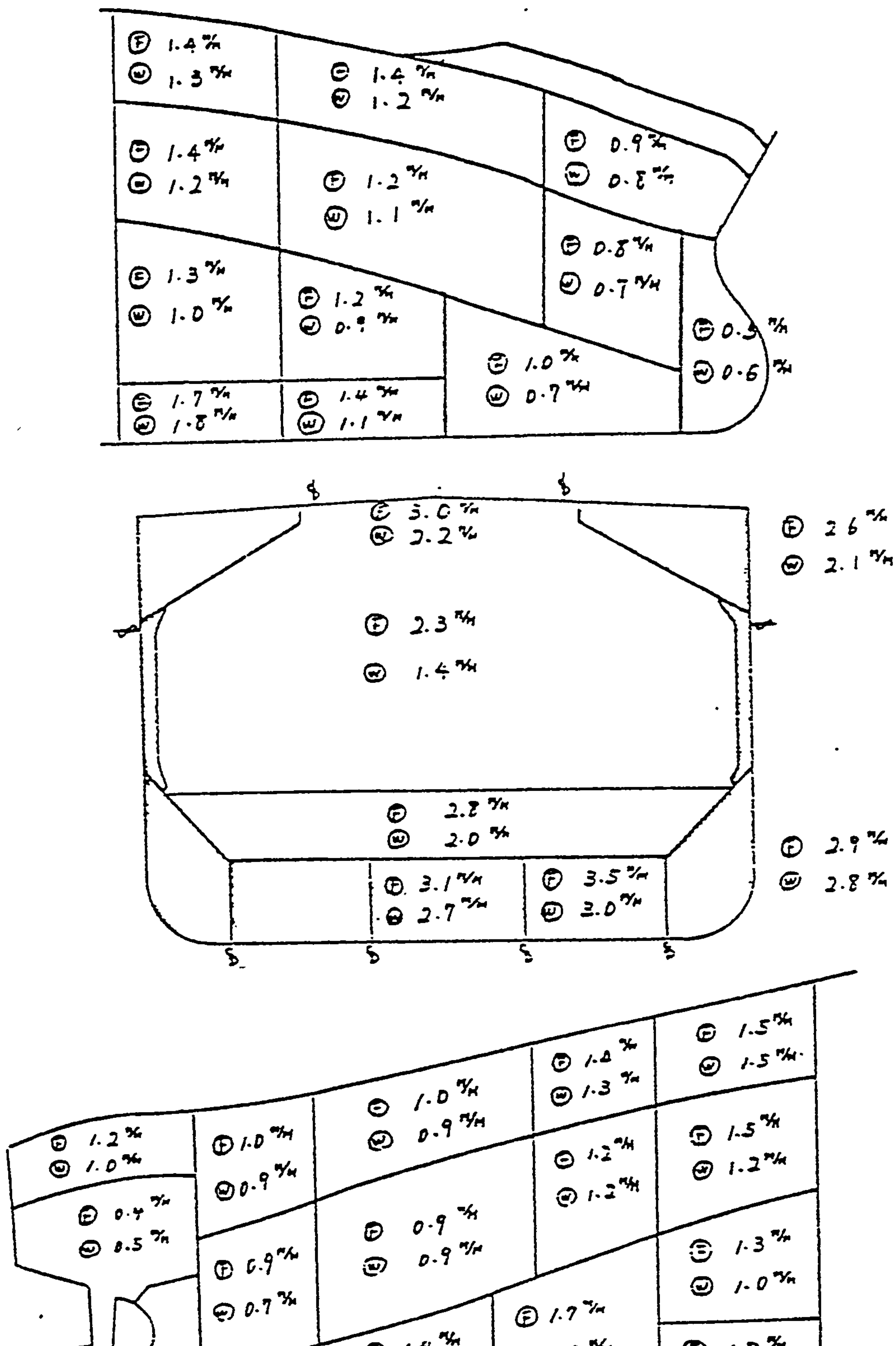


FIGURE 6-7 COEFFICIENT FOR EACH UNIT

In the bulbous bow area, the coefficients reflect the difficulty of the work by the following figures:

Fitting = 0.5m/h (meters/hour)

Welding = 0.6m/h (meters/hour)

IHI staff personnel recognize the variability of manhour requirements, depending on the existence or absence of various conditions. These are categorized into two groups:

a) Those dependent on the structure itself, such as:

Classification of steel: mild steel vs. high strength steel
Type of floor: watertight vs. non-watertight bulkhead
Shape of structure, e.g., flat, curved, cubic (three-dimensional odd-shaped units), width, length, etc.
Number of small pieces involved
Difficulty to achieve accuracy

b) Factors independent of the structure itself, such as:

Weather
Conditions for material preparation
Accuracy achieved in fabrication, fitting, assembly, etc.
Manpower leveling
Equipment availability
Condition of slab
Production procedures
Distribution of manpower

The conditions in the former list are measurable and are subject to scientific evaluation. The latter list contains conditions which vary at different shipyards, depending upon unpredictable factors from a general viewpoint and must be determined independently. Therefore, the conditions relating to variability of the structure itself are addressed in this section.

The coefficients may be influenced by the factors related to the structures. In order to take these factors into account, the following allowances are applied:

a) Material is mild steel (MS) or high tensile strength (HT):
Welding: Coefficient (HT) = 0.90 to 0.95 x Coefficient (MS)

b) Unit contains watertight (T) or Non-watertight (NT) floors:
Melding: Coefficient (T) = 0.85 to 0.90x Coefficient (NT)
Fitting: Coefficient (T) = 0.90 to 0.95 x Coefficient (NT)

c) Unit is curved (C), cubic (C) or Flat (F):
Welding: Coefficient (C) = 0.7 to 0.8 x Coefficient (F)
Fitting: Coefficient (C) = 0.6 to 0.7x Coefficient (F)

2. Coefficients - Detail Estimates

The estimating of manhours must also be performed in more detailed fashion. Where this is required, IHI engineers applied the same principles involved in the creation of coefficients on the charts of Figure 6-5 and Figure 6-7 to develop a Table of Manhours and Efficiency for each assembly unit on the bulker. This data is presented in Table T6-3, a sample showing representative units within the double bottom area.

The conversion ratio figures for each complete unit (15.0 and 16.0 on Table T6-3) correspond to the figures given on Figure 6-5. However, these conversion ratios are further subdivided in the table to show values for the top and bottom panels that made up each unit. These ratios are used to convert actual weight of a unit to an estimated welding length. Likewise, the efficiency coefficients listed in the table are sub-divisions of the coefficients specified in Figure 6-7. For example, Unit 101 lists coefficients for fitting as 3.8 manhours and 2.5 manhours for top and bottom panels, respectively, which is given as 3.1 manhours (average) on Figure 6-7. Note also that the units are specified M.T. (watertight) or not on

TABLE T6-3

TABLE OF MANHOURS AND EFFICIENCY

UNIT	WEIGHT	CONVERT RATIO	WELDING LENGTH	EFFICIENCY M/H FITTING	EFFICIENCY M/H WELDING	MAN-HOURS FITTING	MAN-HOURS WELDING	EFFICIENCY H/T FITTING	EFFICIENCY H/T WELDING	TOT
W.T.	Ton	T 9.4	578 M	3.8 M/H	3.1 M/H	155 H	190 H			
101	61.52	B 6.6	406	2.5	2.4	165	170			
		16.0	984			320	360	5.2 H/T	5.8 H/T	11.0
		T 9.7	571	4.3	3.4	135	170			
111	58.91	B 6.3	371	3.0	2.7	125	140			
		16.0	942			260	310	4.4	5.3	9.7
W.T.		T 9.4	578	3.8	3.1	155	190			
121	61.44	B 6.6	406	2.5	2.4	165	170			
		16.0	984			320	360	5.2	5.8	11.0
		T 9.7	581	4.3	3.4	135	170			
131	59.95	B 6.3	380	3.0	2.7	125	140			
		16.0	961			260	310	4.4	5.3	9.7
W.T.		T 9.4	583	3.8	3.1	155	190			
141	61.99	B 6.6	409	2.5	2.4	165	170			
		16.0	992			320	360	5.2	5.8	11.0
		T 9.7	578	4.3	3.4	135	170			
151	59.58	B 6.3	375	3.0	2.7	125	140			
		16.0	953			260	310	4.4	5.3	9.7
W.T.		T 9.4	581	3.8	3.1	155	190			
161	61.86	B 6.6	408	2.5	2.4	165	170			
		16.0	989			320	360	5.2	5.8	11.0
		T 9.7	581	4.3	3.4	135	170			
171	59.95	B 6.3	380	3.0	2.7	125	140			
		16.0	961			260	310	4.4	5.3	9.7
W.T.	F	T 8.1	315	4.3	3.4	75	95			
102	38.74	B 6.9	268	3.0	2.7	90	100			
	S	15.0	583			165	195	4.3	5.0	9.3
	F	T 8.1	312	4.6	3.6	70	90			
112	38.74	B 6.8	265	3.2	2.9	85	95			
	S	15.0	577			155	185	4.0	4.8	8.8
W.T.	F	T 8.1	315	4.3	3.4	75	95			
122	38.74	B 6.9	268	3.0	2.7	90	100			
	S	15.0	583			165	195	4.3	5.0	9.3
		T 8.1	312	4.6	3.6	70	90			
132	38.74	B 6.8	265	3.2	2.9	85	95			
		15.0	577			155	185	4.0	4.8	8.8

Table T6-3, which affects the determination of the coefficient applied, as explained earlier.

The manhours are determined by applying the formula:

Manhours (H) = Welding Length (M) ÷ Efficiency (M/H)

Efficiency in terms of manhours per ton is computed from these data by the following formula:

Efficiency (H/T) = Manhours (H) ÷ Weight (T)

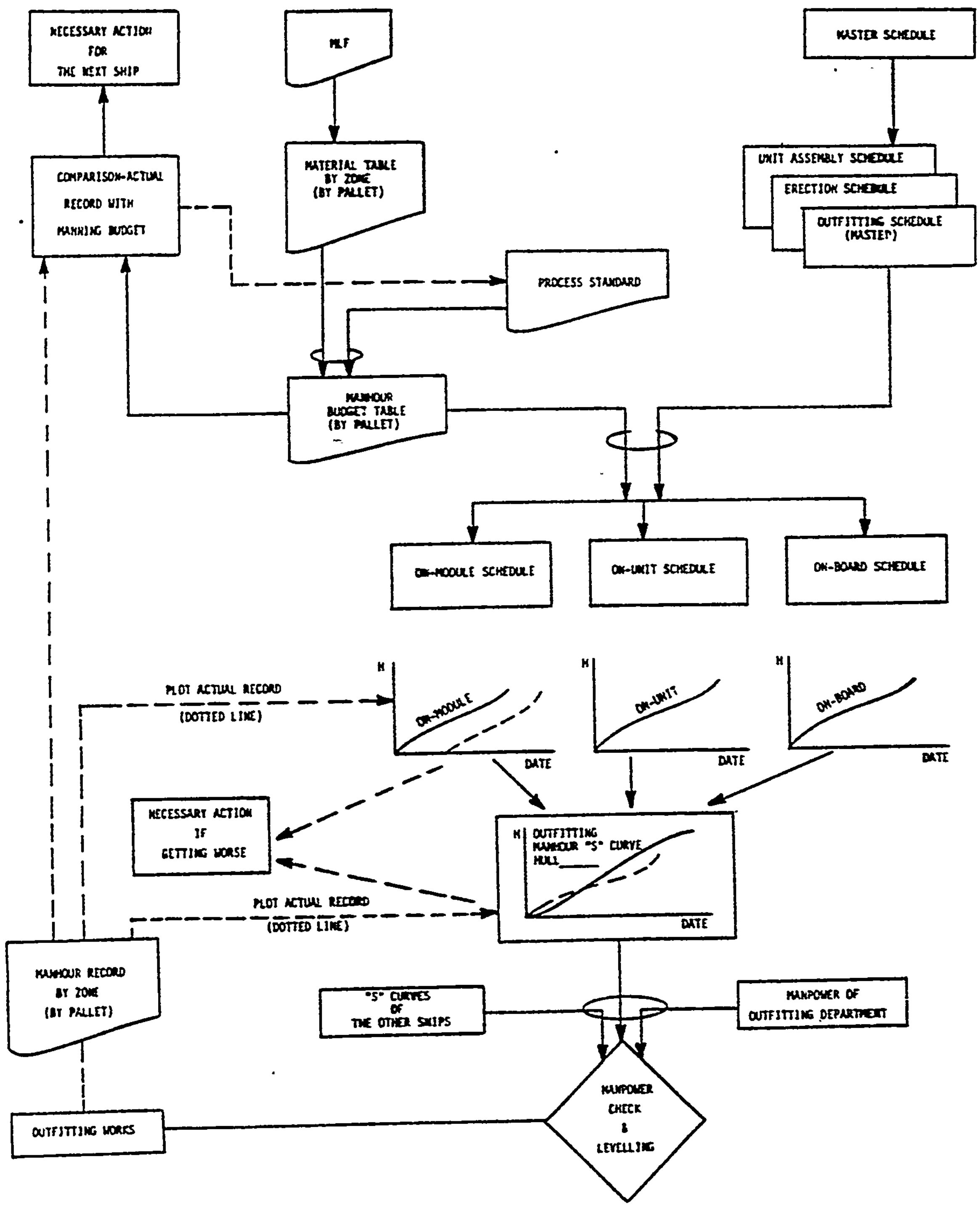
6.6.2 Outfitting

Process standards for outfitting are determined at IHI through the use of actual historical records in combination with the pre-outfitting concept (review TTP final reports: Planning and Production Control; Facilities and Industrial Engineering). The relationship of process standards to the manhour control system as recommended by IHI to Levingston is shown on Figure 6-8.

The on-module pre-outfitting assembly method practiced by IHI, with its standardized work procedures, lends itself readily to formulation of reliable cost standards. The manhours expended on a module assembly are captured and applied as standards and efficiency targets for installation of similar modules on subsequent ships. The data is continually updated and refined over periods of years, which results in increasingly accurate data for application as budgets and goals. The system of manhour goal calculations in the planning process is illustrated in Figure 6-9. An explanation of the details of the procedures shown on this chart is provided in the following paragraphs:

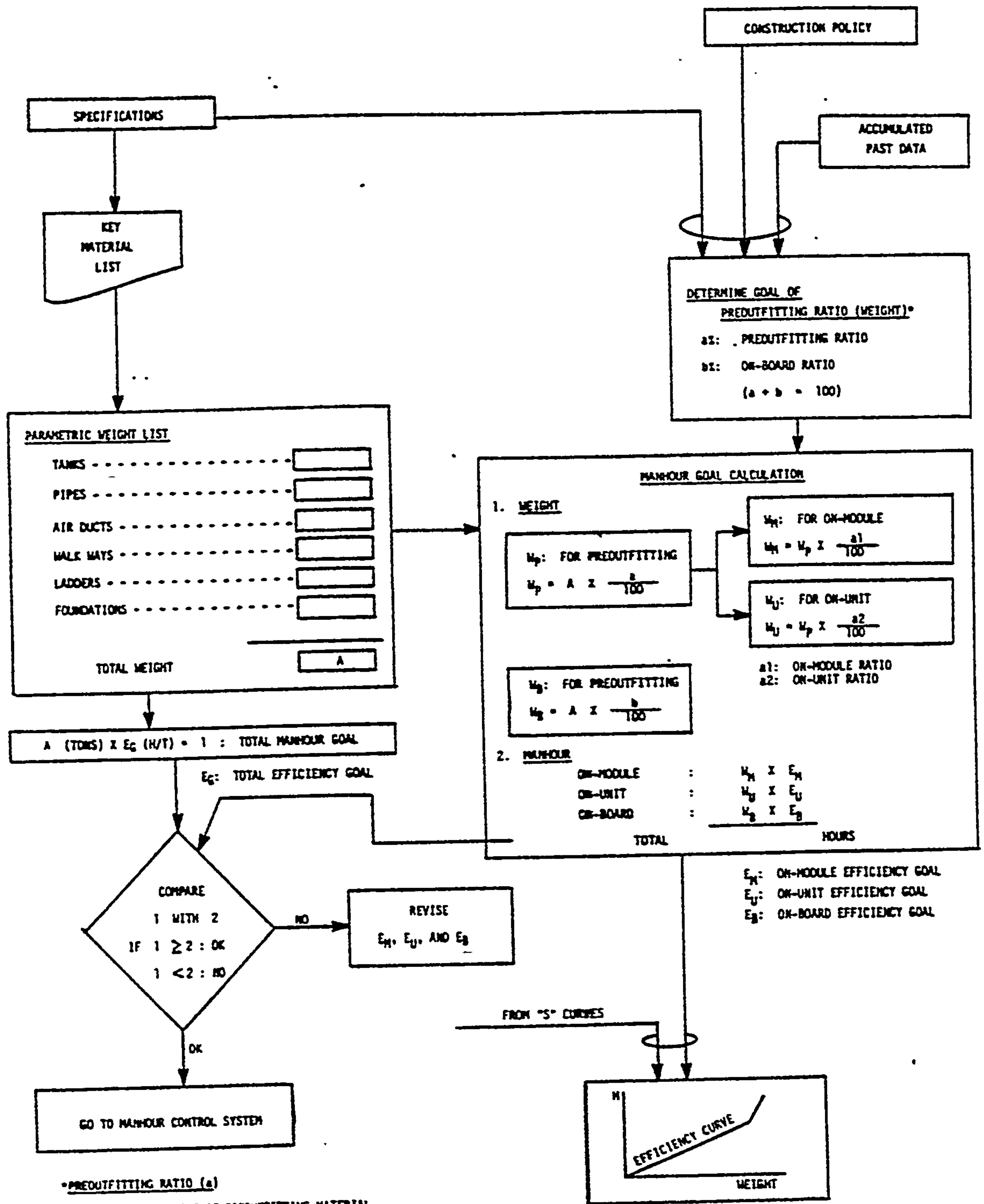
1. Calculation of Weights

IHI recommends that materials collected for installation on a module assembly be recorded on an MLF form (Material List for



RECOMMENDED MANHOUR CONTROL SYSTEM

FIGURE 6-8



*PREOUTFITTING RATIO (a)

$$a = \frac{\text{PARAMETRIC WEIGHT OF PREOUTFITTING MATERIAL}}{\text{TOTAL PARAMETRIC WEIGHT OF OUTFITTED MATERIAL}} \times 100$$

RECOMMENDED OUTFIT PLANNING BY PARAMETRIC WEIGHT

FIGURE 6-9

Fitting). This form contains provision for listing the material and recording its quantity and weight. Figure 6-10 is a form for the MLF proposed by IHI for Livingston. IHI makes a significant distinction between materials whose weights havea linear relationship with manhours from those that do not. The material is classified as being of parametric or non-parametric weight, according.to the following definitions:

Parametric Weight - The weight of material considered to have a linear relationship with manhours required for its installation. Examples: pipe, valves, walkways, etc.

Non-parametric Weight - The weight of material that does not have this linear relationship with manhours. Exmples: main engines, anchors, etc.

IHI recommends the determination of materials that can be classified as parametric, and the summation of these weights for a ship in the preliminary planning steps at the design stage. These materials should be assigned separate pallet numbers during the development of theMLF list.

6.6.3 Developing Standard Times

It is apparent that the key to development of reliable process standards and cost standards for outfitting functions is dependent upon standardized, uniform working procedures and accurate manhour reporting, as was mentioned in the case of steel construction. This is accomplished by maintaining charts and graphs of actual productivity, by providing feedback on the accuracy of the projected standards, and by taking corrective action when discrepancies appear.

Examples of some cost standards recommended by IHI for Livingston on outfitting items are given in Table T6-4. This table exemplifies the

MLF - Material List for Fitting	Hull	Pallet	Work Order No.	Written By

Group*	Description	Installation No.	Qty.	Wt.	Note

*Group: Further Classification according to the work sequence within a unit of work as defined within a pallet.

PROPOSED MLF (MATERIAL LIST FOR FITTING)

FIGURE 6-10

TABLE T6-4

EXAMPLES - COST STANDARDS

Work Description	Cost Standard
Slab layout	5^H per module
Foundation setting	3^H per piece
Machinery setting	8^H per machinery
Prefabricated pipe fitting (less than 60 lb) (over 60 lb)	 2^H per piece 3^H per piece
Valves (less than 60 lb) (over 60 lb)	 1.5^H per piece 2.5^H per piece
⋮	⋮

cost standards that can be developed by using the experience of knowledgeable people combined with historical data. Figure 6-11 illustrates the use of cost standards in the determination of budgets for building a module. The total budget is a summation of individual budgets for each craft, obtained by using the cost standards, applying them to the MLF items listed for each craft. Update of standards is obtained by comparing actual data with budgeted data and revising the standards as necessary.

The data pertinent to development and use of process standards for on-module outfitting is illustrated on Figure 6-12. This material and man-hour table contains the relevant data including 'parametric weight, budgeted manhours and actual manhours for a representative module built IHI.

6.7 USES OF COST STANDARDS

The process standards section of this report explains how methods and processes are determined within the gate system concept. The establishment of each gate signifies the process performed within that gate.

This section has dealt with the establishment and definition of control parameters for measuring work. As mentioned, IHI uses welding length as the main parameter to measure work in the assembly type processes. This data base allows the calculation of the amount of work to be processed through each gate (at the preliminary planning stage), and the amount of work required to produce an assembled unit (at the detail level).

The information obtained from process standards and cost standards may be used to construct charts on each unit, similar to the information as illustrated on the following page.

Craft by Craft:

MLF X Cost Standard = Craft (1) Budget

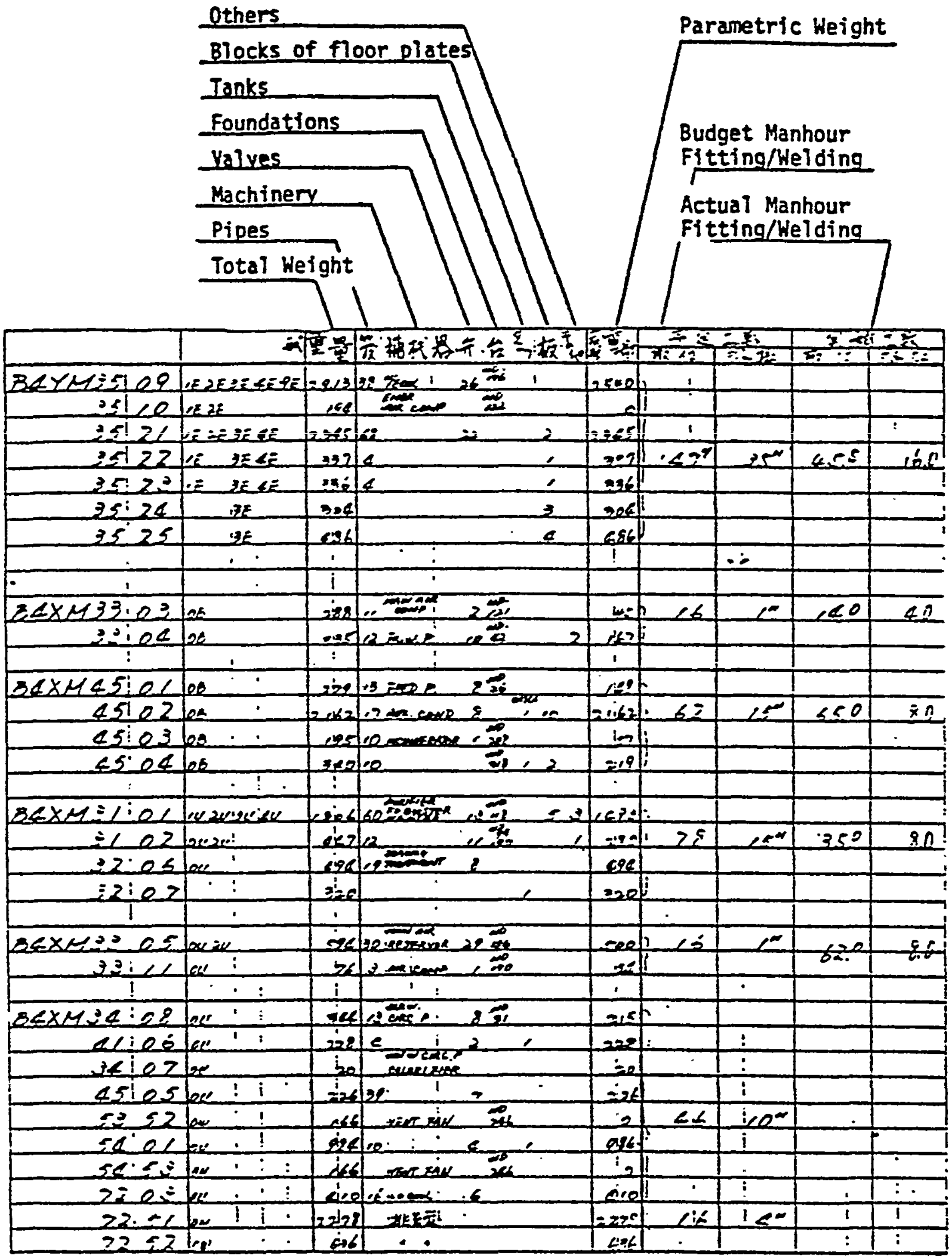
MLF X Cost Standard = Craft (2) Budget

MLF X Cost Standard = Craft (3) Budget

SUM (1) + (2) + (3) = Total Budget by Module

BUDGET CALCULATION BY MODULE

FIGURE 6-11



IHI MATERIAL & MANHOUR TABLE FOR MODULE

FIGURE 6-12

UNIT	SIZE	WEIGHT (TON)	WELD LENGTH		MANHOUR			DAY					
			AWL	MWL	PANEL	FIT	HELD	1	2	3	4	5	6
101(T)	40′x12′	39.8	80′	140′	75H	70H	185H	4W	4W	6W	6W	6W	6W
(B)	40′x12′	50.4	80′	105′	75H	55H	160H				4W	5W	

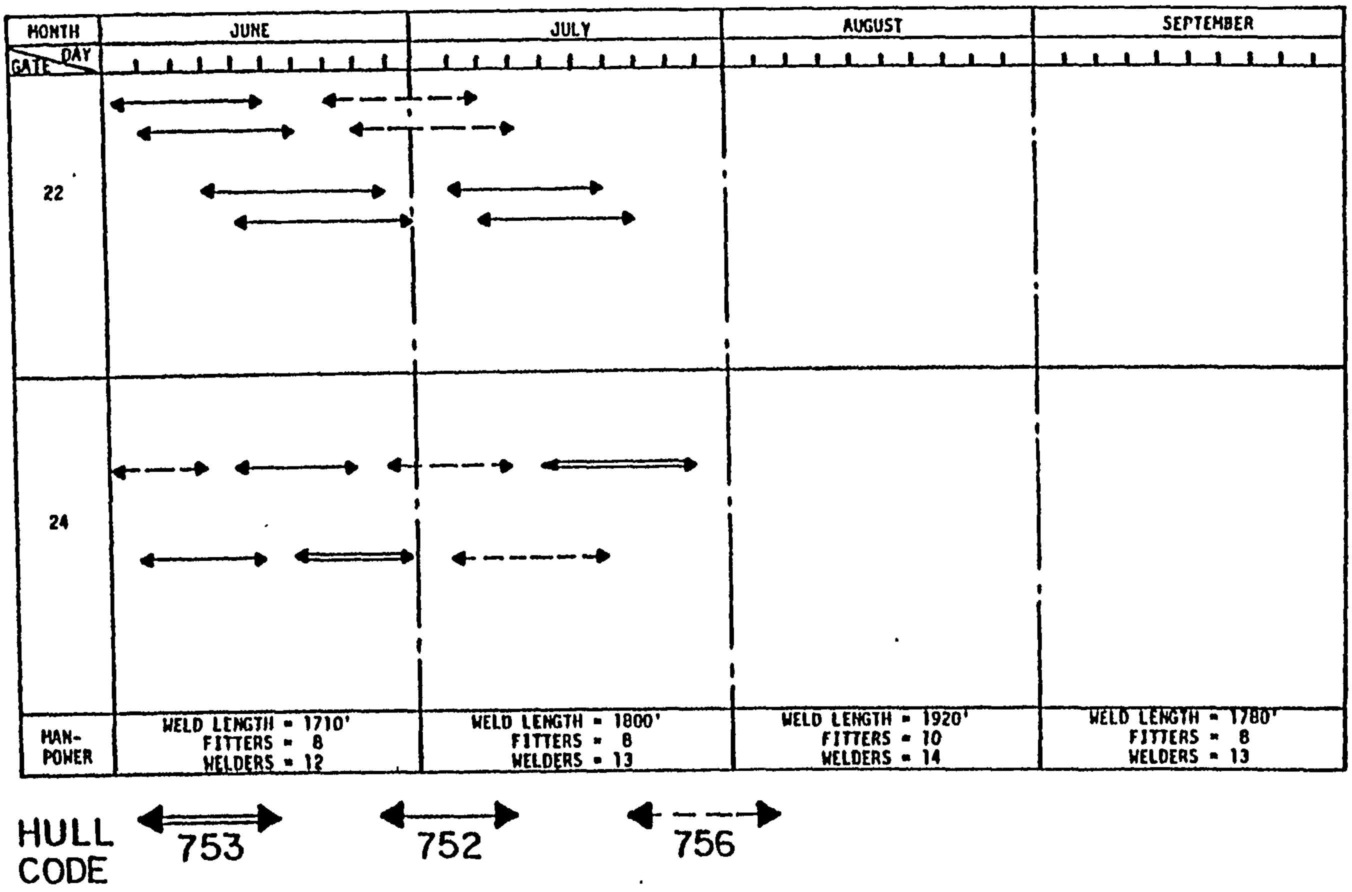
Symbol Explanations:

Fitting	MWL = Welding Length by Manual Process
Welding	AWL = Welding Length by Automatic Process
Panel Joining	T = Top Panel
WL = Welding Length	B = Bottom Panel
H = Hours (Manhours)	M = Workers (Fitters, Welders)

At this point, final decisions are made concerning the assignment of units to designated gates. Consideration of such items as area of slab required (due to size of the unit) and amount of work required (for conversion from manhours to manpower) is involved. Workloads can then be leveled to accomplish jobs by priority and within gate capabilities.

These data are converted to long-term schedules (See Example - Figure 6-13) and short-term schedules (See Example - Figure 6-14). The long-term schedule, covering a four-month period, accounts for production of each hull under construction. The short-term thirty-day schedule, emphasizes the operations being performed on each unit at each gate.

A detail schedule can be issued for each assembly unit from this standard data. An example of such a schedule is shown as Figure 6-15. This schedule specifies the work performed to accomplish the fitting, welding, panel joining, and final assembly of the unit.

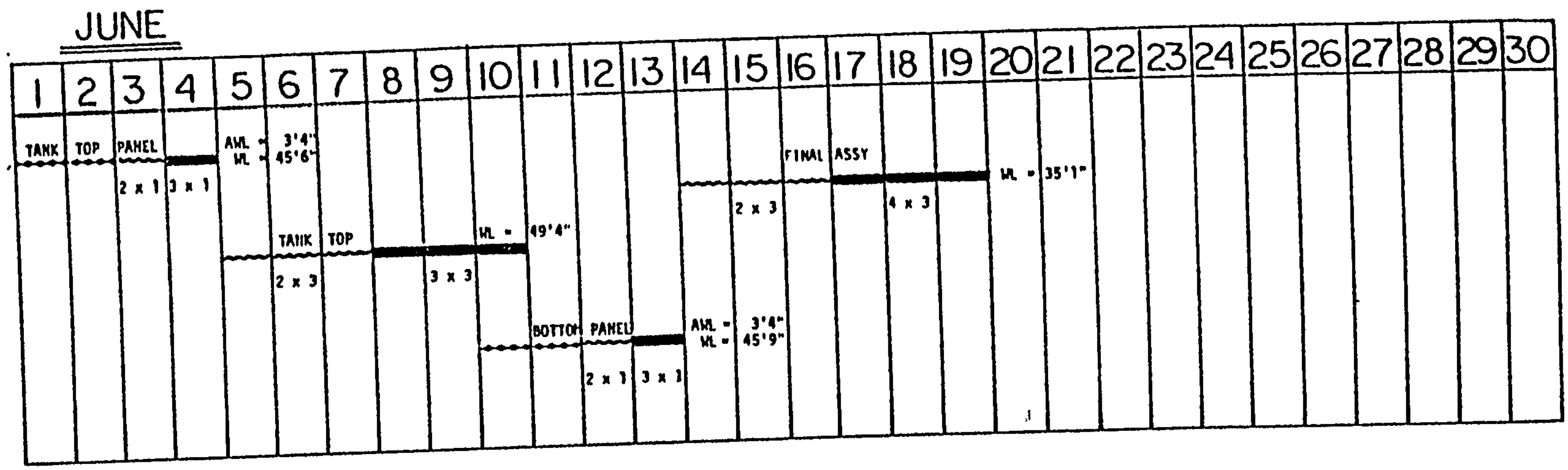


LONG TERM SCHEDULE (SAMPLE)

FIGURE 6-13

GATE	UNIT	SIZE	WEIGHT	WELD LENGTH		MANHOURS																						JULY			
				AWL	MHL	FIT	WELD	2	3	4	5	6	9	10	11	12	13	16	17	18	19	20	23	24	25	26	27	30	1	2	3	4
	101	40'x 15'	50.6 tons	80'	170'	75^{H}	180^{H}	FIT					WELD					OUTFIT				INSPECT		PAINT					ERECT			
22																																

FIGURE 6-14 SHORT TERM SCHEDULE (SAMPLE)



LEGEND

PANEL JOINING

FITTING

WELDING

MANNING (EXAMPLE):

2 x 1 MEANS 2 WORKERS FOR 1 DAY

TOTALS

AWL (AUTOMATIC WELD LENGTH)	= 6'8"
WL (MANUAL WELD LENGTH)	= 175'10"
FITTING MANHOURS	= 128 HR
FITTING EFFICIENCY	= 1.4 FT/HR
WELDING MANHOURS	= 218 HR
WELDING EFFICIENCY	= 0.8 FT/HR

DETAIL SCHEDULE (SAMPLE)

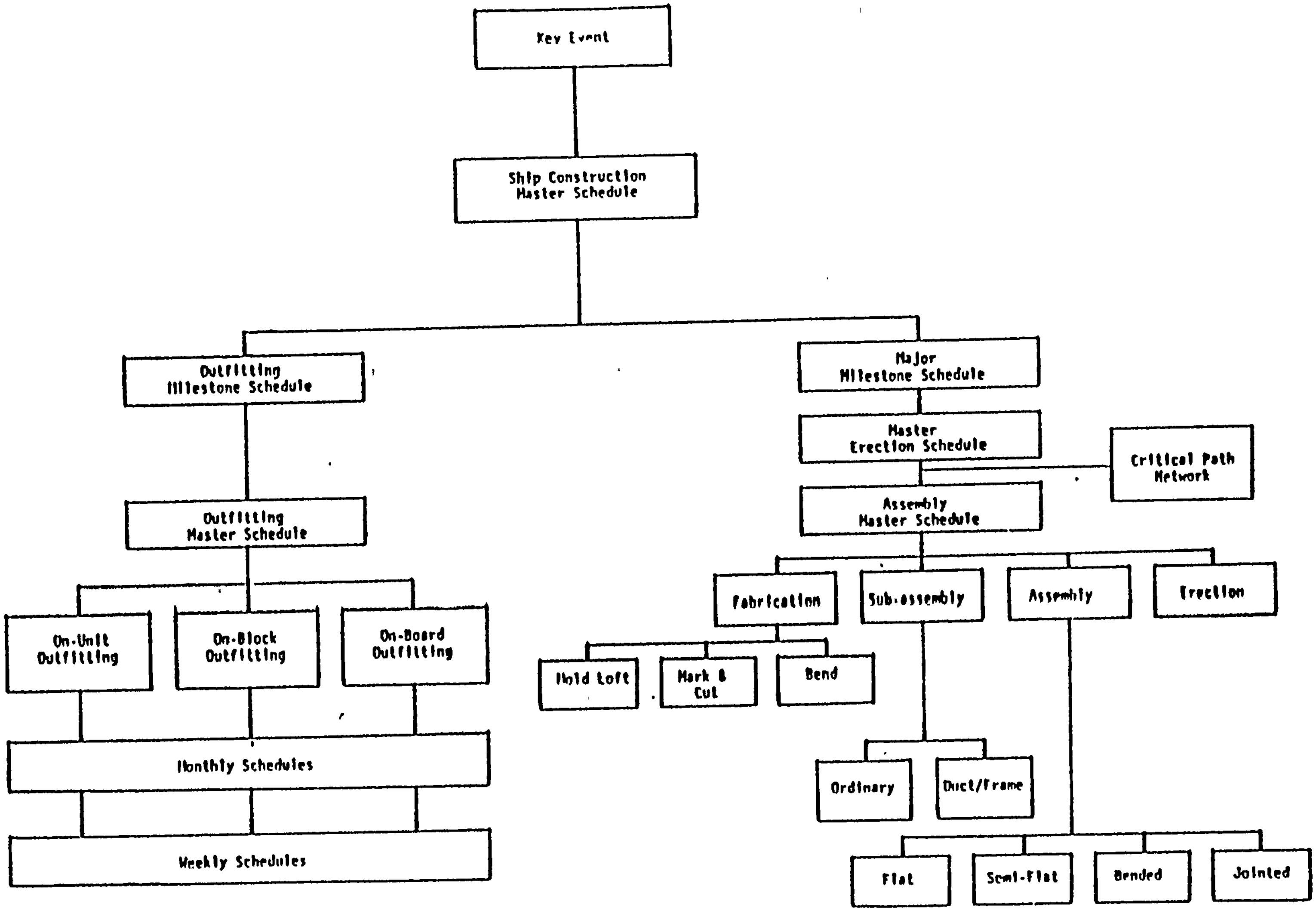
FIGURE 6-15

The welding lengths and efficiency ratios computed in the manner described in this section provide the data for calculation of manhours for each process. This is sub-divided into the total number of manhours required per craft (fitters and welders in the example). The number of workers required is determined by the welding requirements at each stage of assembly. The schedule is, ’therefore, influenced by the amount of work required on each unit, the calculated manpower needs, and the other work being processed through that gate.

6.7.1 SCHEDULING APPLICATIONS

A thorougb discussion of the planning and scheduling system at IHI is included in the TTP Final Report on Planning and Production Control. In that report, the development of schedules ranging from broad ship construction Master Schedules to the detailed sub-schedules for each process is explained. A summary of the applicable portions of the report which pertain to the use of cost standards is presented on the next page.

Figure 6-16 presents the hierarchy of schedules developed from the primary master schedule. The Ship Construction Master Schedule is the top-level construction schedule for all work in a given yard. When a new ship or ship program is introduced into a yard, a suitable time frame must be allocated to its construction within the overall building schedule of the yard and with due regard to the delivery schedule established by the Head Office. This schedule is prepared by the Production Control Group of the shipyard through an estimation of the required manhours per month based on the throughput rates established for the yard facilities and work force. These throughput rates are calculated during the development of cost standards as detailed in this section. In these overall scheduling



HIERARCHY OF SCHEDULES

FIGURE 6-16

applications, gross measurement elments (e.g., hours per ton) are sufficient for this level of planning.

Master Schedules are next developed for Erection, "Assembly and Outfitting stages for use as guidelines in developing the more detailed sub-schedules at each process stage.

The Erection Master Schedule is the first working schedule prepared. This schedule establishes the erection times for each unit in each zone of the ship. This schedule is structured taking account the following:

1. Proper erection sequence
2. Erection process
3. Capacities of assembly yard
4. Capacities of storage yard
5. Crane capacities
6. Capacities of outfitting and painting shops
7. Capacities of erection work groups

The assembly Master Schedule is prepared to show the time requirements for each unit during the assembly process. Each type of unit is sorted by the type of fabrication process required for its production into the following:

- Flat Units (e.g., center double bottom units of the midship section)
- Semi-flat Units (e.g., side double bottom units)
- Curved Units (e.g., bow and stern sections)
- Joined Units (e.g., two or more units joined to form a "Grand Unit")

Units are scheduled for assembly in a sequence and flow designed to maintain a full load and smooth flow throught the assembly areas using the following criteria:

1. Determination of the number of assembly days per unit
2. Assembly area requirements for each type of unit
3. Capacities of each process lane
4. Optimum manloading of each process lane
5. Outfitting requirements on units having major outfitting
6. Painting requirements
7. Storage requirements
8. Flow of structurally similar units in series

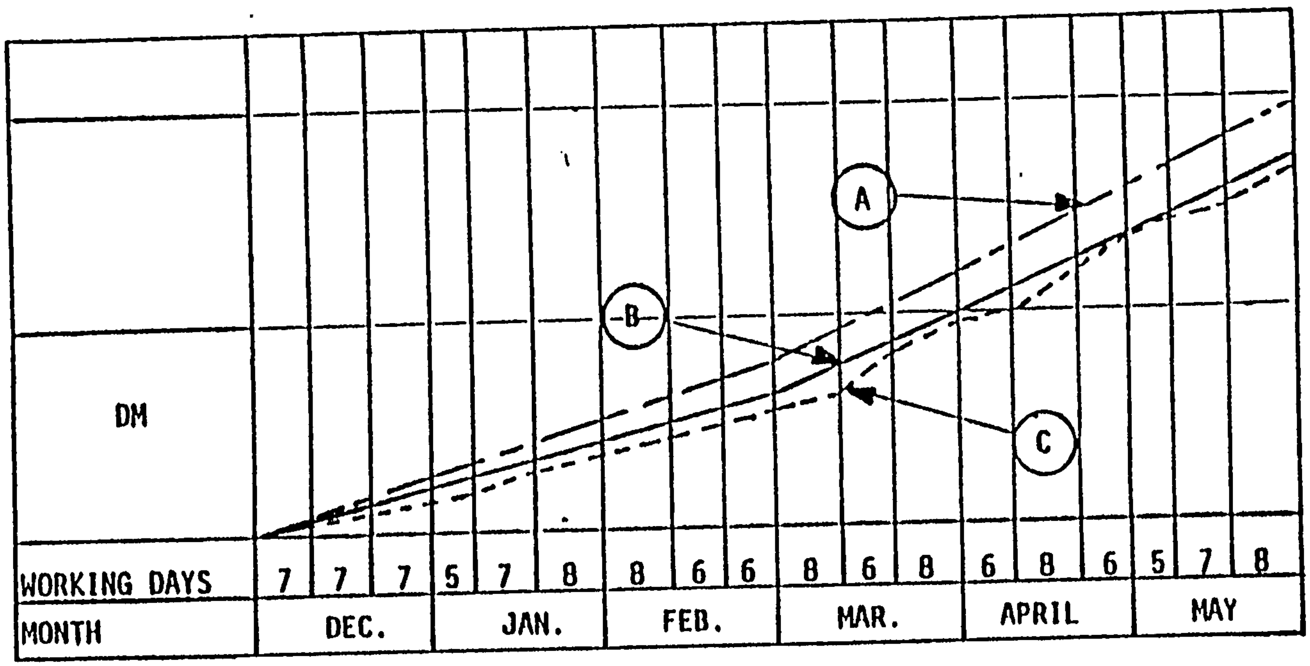
The number of required assembly days for the different types of units is a standard in the yards. This standard is shown in Figure 6-17. Also, the calculation of manloading is standardized through the computation of weld .deposit required on the various units. Weld deposit (DM or Deposit Meters) per month per assembly area is plotted on a graph and compared to the established capacity of that area. If the plot shows that the scheduled work exceeds that of the established capacity, work may be shifted to other assembly areas, subcontracted or, in extreme cases, the erection date may be rescheduled. Figure 6-18 depicts a plot of a proposed assembly schedule versus the established capacity of a specific assembly area.

Using the information contained in the Assembly Master Schedule, Hull Construction Workshop -engineers prepare detailed schedules for each sub-stage of the fabrication, assembly and erection stages. No overall schedule is prepared for each of the production stages; rather, the schedules detail the required dates for lofting, marking, cutting, bending,

PART	UNIT	ASSEMBLY	JOIN
FORE	Curved Skin	8	
	Semi-Flat	7	
	Pre-Ere.		15 - 20
MID	Bottom	7	7 - 10
	Skin	7	7 - 10
	Bilge	7	10 - 15
	T. Bhd.	6	
	L. Bhd.	6	
	Deck	6	10
E/R	Engine Bed	8	10 - 20
	Curved Skin	8	
	Semi-Flat	7	
AFT.	Curved Skin	8	
	Semi-Flat	7	
	Pre-Ere.		15 - 20

REQUIRED ASSEMBLY DAYS STANDARD PER HULL STRUCTURAL TYPE

FIGURE 6-17



(A) ASSEMDLY CAPACITY

(B) PROPOSED ASSEMBLY SCHEDULE

(C) LATEST ACTUAL COMPLETION ASSEMBLY SCHEDULE

COMPARISON FOR ASSEMBLY SCHEDULING

FIGURE 6-18

sub-assembly, etc., to meet the assembly dates established in the Assembly Master Schedule.

Detailed sub-schedules are prepared for each operation in the fabrication process. These schedules cover all of the work required for each ship set of parts, pieces, and sub-assemblies.

Mold loft schedules are prepared for each unit of a given ship. The schedules define each day’s activity for the mold loft for each unit. Lofting requirements are specified in the working drawings and these requirements and the daily schedule are coordinated by the Production Planning and Engineering group.

The sub-schedules for marking, cutting, and bending are developed for each of the different process lanes of the fabrication ships. These process lanes are discussed in the Process Standards section of this report and include:

1. Cutting internals
2. Cutting panel or skin plates
3. Cutting and bending shapes
4. Bending plates

Each of these process lanes requires individual schedules for marking and cutting. Bending schedules are prepared for those lanes engaged in this activity.

These sub-schedules are prepared on the ultimate need date for the components for sub-assembly or assembly, and the length of time required to process bent or curved pieces versus simpler parts and pieces. Consideration is also given to any pieces requiring special cutting such as beveling which necessitates a longer process time and which should be removed from the continuous process flow, and to arranging a flow of similar or identical pieces through a given work station to maximize the production rate (e.g., plates moving through a flame planing station).

Sub-assembly of steel components is performed at the end of the fabrication process lanes. The scheduling performed for components undergoing fabrication is primarily oriented toward completing all necessary components to support a smooth flow through the sub-assembly process. Sub-assembly schedules are constructed so as to support the assembly of units, just as the fabrication schedules support the buildup of the sub-assemblies.

Assembly sub-schedules are prepared for each type of unit, i.e., flator curved, and for each assembly area and each sub-stage. The Block Assembly Plans, Assembly Specification Plans and the Assembly Master Schedule are the basis for these schedules.

Production Planning and Engineering group personnel develop the sub-schedules on the basis of the total welding requirements-for each unit which also dictate the manloading for the assembly area. The use of cranes is also carefully scheduled especially for the heavy lifts after assembly of the units has begun.

The erection sub-schedules are developed in concert with the Erection Master Schedule by detailing the steps involved in preparation, landing and joining the individual units.

Fitting and welding manhours are calculated for each step in the erection sequence and the steps are "set back" from the preceding step the appropriate number of days to allow for the accomplishment of the requisite tasks. When completed, the schedules are adjusted to coincide with the launch of the ship and with the start of the erection of the next ship scheduled for that building basin.

In parallel with the scheduling of the steel work through the Hull Construction Workshop, outfitting scheduling is developed to reflect the procurement, fabrication, sub-assembly and installation of outfitting components. The schedules coincide with the various production stages of hull work as it proceeds through the sub-assembly, assembly and erection processes.

6.7.2 MANPOWER PLANNING

The manpower planning process involves several distinct steps to ascertain the precise numbers of the different types of personnel required for hull construction and outfitting. Essentially, this planning evolves from an overall estimate of the manhours required for each production stage (i.e., lofting, fabrication, assembly, erection, outfitting) to a scheduling of these manhours on a month-by-month basis and, by means of these man-loading schedules, to an identification and allocation of appropriate personnel to the work groups at each work station. Monitoring of these manhours is then accomplished by means of production control charts maintained by the workshop staff-groups.

The overall estimate of manpower is performed by the Production Control Department by first breaking down the estimate into the three main areas of hull construction, fitting and painting.

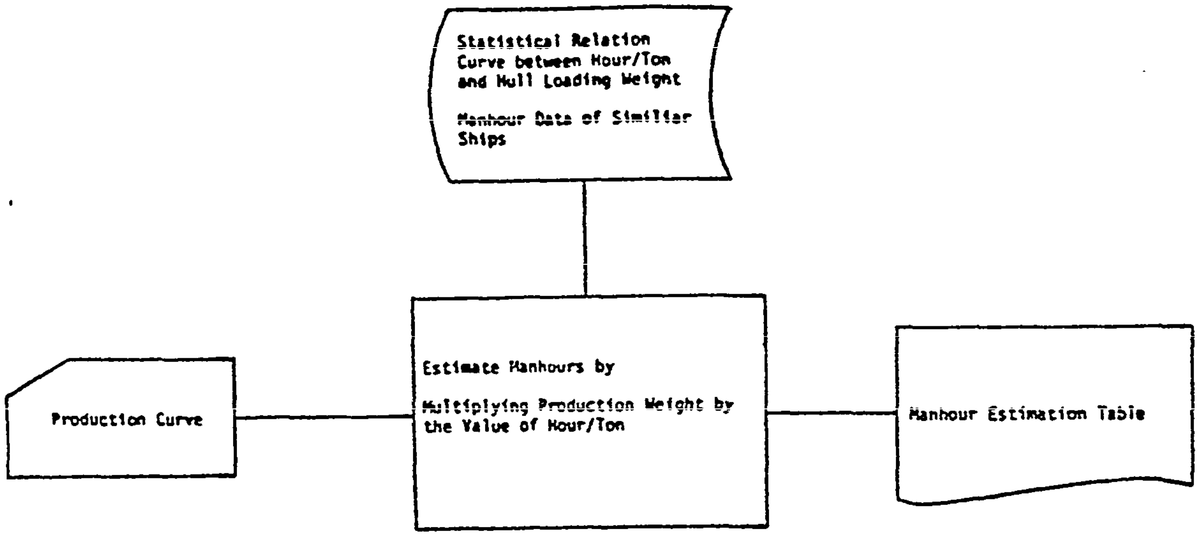
Using the ship specifications and a Budget Control List (prepared from historical data) and additional historical data from similar ships, . the Production Control Planners estimate the number of manhours required for hull construction based on the weight of the hull, probable welding lengths, and probable cutting lengths. Outfitting manhours are estimated using the weight of fittings and the electrical cable length. Main machinery weight is not included in this calculation. Painting is estimated by weight and by the area requiring painting.

These manhours estimates are plotted in a series of curves which are then aggregated in a “Production Curve” to show the total manhours requirement for the ship over the time allocated in the Shipyard Master Schedule for ship construction. Figure 6-19 shows the development of this overall Production Curve.

Using the Production Curve, manhours are computed in terms of manhours per ton for each stage of production. The output of this planning is a Manhour Estimation Table which details the hours per ton for the various operations of fabrication, assembly, erection and outfitting.

In hull construction, the number of welder hours are determined together with the number of support personnel. In this workshop, welding is considered the primary activity and all effort is oriented toward providing a smooth flow of work through the welding processes stall times. Support personnel are considered to be all others who perform tasks concerned with the transport, preparation and removal of material to and from the welding stations.

In outfitting, the number of manhours is determined for the various fitters in each of the fitting sections (i.e., pipe, interior, deck machinery, electric) per ton of fitting material at each production stage. Figure 6-20 depicts the development of the Manhour Estimation Table and Figure 6-21 provides an example of this table.



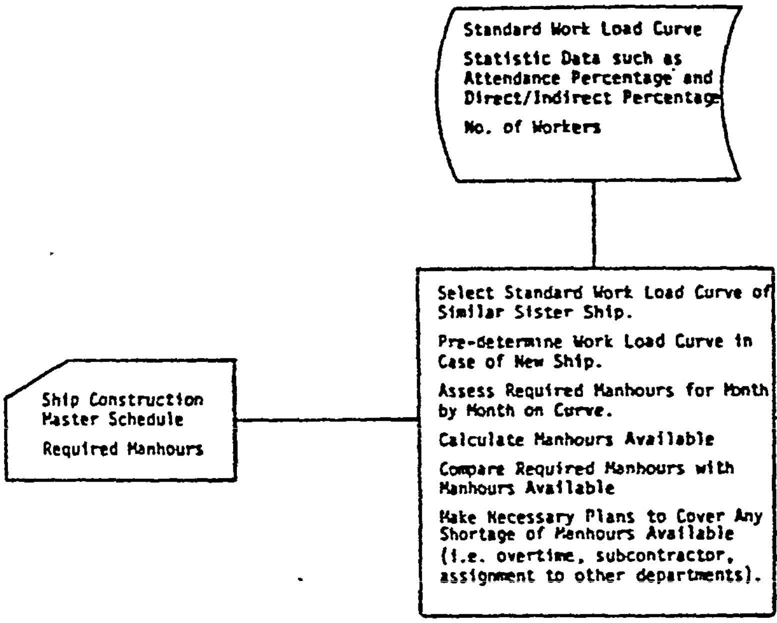
MANHOUR PLANNING

FIGURE 6-19

	SNO 1000					
Deadweight						
Kind of Ship						
L x B x D x d						
Owner						
Ship Name						
Classification						
Keel Laid						
Launching						
Delivery						
	MH	WT	H/T	m	H/m	Σ
Pipe Work						
Interior Work						
Deck Work						
Machinery Work						
Electric Work						
Control Work						

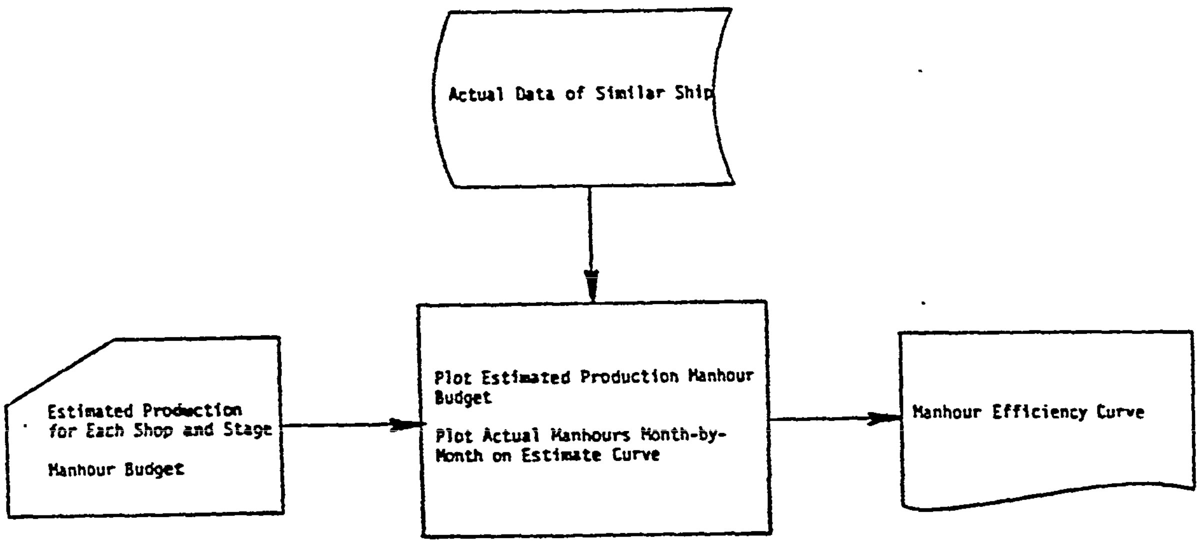
MANHOUR ESTIMATION TABLE

FIGURE 6-20



WORK LOAD SCHEDULING

FIGURE 6-21



MANHOUR EFFICIENCY CONTROL

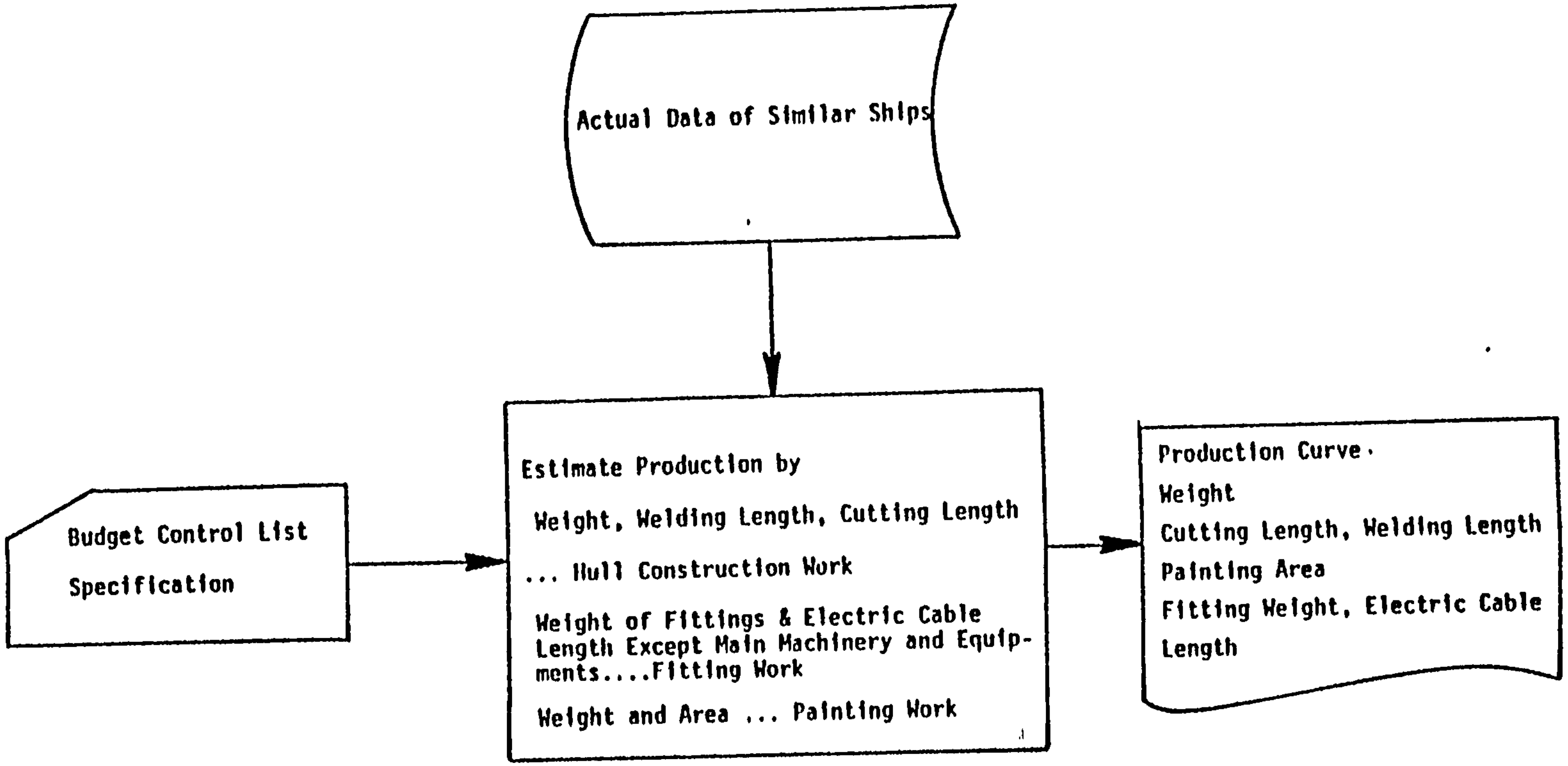
FIGURE 6-22

The application of the hull construction and fitting manhours across the ship construction time frame consists of the identification and plotting of the number of manhours required for each activity in each sub-stage and stage of production. The summation of these manhours forms the manhours curve for the ship being planned. Comparison of this curve with a “standard” curve from a previous and similar ship indicates its facility and provides an assessment of questionable areas. The purpose of this assessment is to determine the number of manhours required over the period of ship construction and to compare the requirements with the available manpower month-by-month.

The output of this overall workload scheduling is used to level-load the production workshops and to ensure the availability of sufficient manpower for all ships in process. Figure 6-22 illustrates the development of this Work Load Schedule.

Estimated manhours for each shop and for each production stage are closely monitored each month to ensure that the forecast hours are sufficient to accomplish the scheduled work. Work efficiency is also monitored by means of a comparison of actual hours expended to those expended on a prior similar ship. This control is exercised within the individual workshops through monthly and weekly shop schedules, manpower charts, and performance control charts developed by the Production Planning and Engineering staffs. This information is aggregated into the overall manhour efficiency curve by the Production Control group. Figure 6-23 shows the development of this curve.

Manhours are continually weighed against actual manhours used on previous ships and by the various factors of manhours/ton, manhours per



PRODUCTION PLANNING BY WEIGHT, CUTTING LENGTH AND WELDING LENGTH

FIGURE 6-23

length of weld deposited, cut lengths, outfitting weights, cable lengths, etc. This manpower planning, when combined with the production planning and scheduling, forms a complete framework of data for the performance of all work in each area of production.

6.8 LIVINGSTON APPLICATIONS

The application of the IHI cost standards program first requires . initiation of a corresponding system of process standards. A good process standards program provides a systematic approach for establishing, documenting, and issuing standard work methods to the proper people. This is a necessary pre-requisite to implementation of an effective cost standards program through which the performance of standardized *processes* are measured and reported in terms of throughput rates and efficiency.

Livingston has actively sought to implement many of the IHI system concepts that are the necessary foundations for a sound process standards program. Material flow within the shipyard has been defined, the gate system *has* been implemented, and material flows within certain areas have been established. Material lists were revised to reflect new items including unit system numbering, piece counts per component, and process flow by gate number. Figure 6-24 represents a typical Levingston Bill of Material as instituted since implementation of IHI planning and scheduling technique, showing inclusion of this type of data and its format. The section of this report on Process Standards describes Livingston's application of IHI technology in the implanentation of this technique. Particular emphasis was placed on the employment of process standardization techniques in the assembly functions, where written procedures and guidelines were issued for each typical unit of the hulls under construction.

FIGURE 6-24

TYPICAL POST-IHI BILL OF MATERIAL

MATERIAL LIST FOR STEEL
LEVINGSTON SHIPBUILDING CO.

HULL NO. 751
UNIT NO. 201
CUSTOMER
SHEET 1 OF 2 ALT

☒ ORANGE ☐ GULFPORT ☐ WOODVILLE ☐ TYLER

	BY	CHKD	DATE
ENGINEERING			
MOLD LOFT			
PROD CONTROL	[illegible]		2-6-[illegible]

DWG NO.	CUT'G NO. OR SUB-ASSY	PIECE NUMBER	DESCRIPTION	QUANTITY P	QUANTITY C	QUANTITY S	QUANTITY T	ITEM S-ITEM	PROCESS GATES	LINE	TOTAL IN-SQ FEET	WEIGHTS UNIT	WEIGHTS TOTAL	NC TAPE	MATERIAL REMARKS/CUT FROM	PAINT	MAT'L SPEC.	REQ'N NO.	REQ'N LN
	201-1		Bottom Shell		1		1	13-01	20 23	1			8900						
		1	PL .7087" x 87" x 36'-10"		1		1	13-01	11	2	267	17.94	7127		PL .7087" x 88" x 37'-0"	[illegible]	ABS A	[illegible]	7
		2	PL .5906" x 118" x 36'-10"	1		1	2		11	3	728	[illegible]	17559		PL .5906" x 118" x 37'-0"			[illegible]	1
		3	FB ½" x 6" x 36'-10"	1		1	2		11	4	74	10.21	756		FB ½" x 6" x 37'-0"			[illegible]	4
		XM-28	WT 9 x 20 x 36'-10"	2		2	4		11	5	148	20	2960		WT 9 x 20 x 37'-0"			[illegible]	6
	201-2		Tank Top		1		1	13-01	20 22	6			33584						
		5	PL .7087" x 107" x 36'-10"		1		1	13-01	11	7	329	18.90	9541		PL .7087" x 108" x 37'-0"	[illegible]	ABS A	[illegible]	2
		6	" x 108½" x 36'-10"	1		1	2		11	8	667	"	19303		PL .7087" x 109" x 37'-0"			[illegible]	7
		XM-[illegible]	WT 10.5 x 25 x 36'-10"	2		2	4		11	9	148	25	3700		[illegible] x 37'-0"			[illegible]	8
	201-3		C. Vertical Keel		1		1	13-01	22	10			4156				ABS A		
		4	PL .4688" x 70⅞" x 36'-10"		1		1	13-01	10	11	217	19.15	4156		PL [illegible] x 72" x [illegible]	[illegible]		[illegible]	1
	201-4		[illegible] Floor @ 13'-[illegible]	1		1	2	13-01	15 22	12			9278				ABS A		
	-5	7	PL .4688" x 70⅞" x 36'-10"	1		1	2	13-01	10	13	434	19.15	8311		2 PL [illegible] x 72" x 37'-0"	[illegible]		[illegible]	1
		XPF-35	FB .4688" x 6" x 5'-7⅞"	9		9	18		12	14	101	9.57	967		6 FB [illegible] x 6" x 18'-0"			[illegible]	7
	201-6		[illegible] Floor @ 5'-3"					13-01	22	15			9769				ABS A		
	-7	8	PL .5512" x 70⅞" x 36'-10"					13-01	10	16	434	22.51	9769		PL .5512" x 73" x 37'-0"	[illegible]		[illegible]	4
	211-1		Int Assbly	14		14	28	13-01	13 22	17			33516				ABS A		
	211-2	XF-101	PL .5512" x 70⅞" x 5'-2⅞"				14	13-01	10	18	420	22.51	9450		PL .5512" x 73" x 18'-0"	[illegible]		[illegible]	4
		XF-102	"				14		10	19	420	do	9450		2 PL do			[illegible]	4
		XPF-44	FB .4688" x 4" x 8'-[illegible]				12		12	20	108		664		16 FB [illegible] x 4" x 20'-0"			[illegible]	6
		XPF-43	FB .4688" x 6" x 5'-0⅞"				52		10	21	280		1688		14 FB [illegible] x 6" x 21'-0"			11 [illegible]	8
		XPF-81	FB .5512" x 4" x 0'-11"				11		10	22	11		184		Remnants				
										23									
										24									
										25									
										26									

7-31-18 [illegible]

IHI recommended the use of welding length as the control parameter for measuring performance standards, and subsequent calculation of cost standards. Livingston has not adopted the use of this parameter, but chooses to continue *using* tonnage figures as cost parameters at the present time. This is not because the use of welding length is of questionable value, but rather because the Livingston record-keeping systems are based on collecting tonnage figures. The status and plans of Livingston are described in the following paragraphs, addressing each of the two methods proposed by IHI to obtain welding length:

1) Measurement from drawings: The IHI approach of measuring weld length from key plans is very accurate, but quite time-consuming. Also, to be most useful for planning purposes, the measurements are needed considerably sooner than actual production is started. At IHI, much of the planning and scheduling is performed by a consolidated group of design engineers, planners, and production engineers during design development. This work is initiated upon issuance of yard plans, or working drawings, which usually begins about three and one-half months prior to keel lay (refer to the TTP Final Report on Engineering and Design). This kind of timing has not occurred at Livingston for contracts on initial-ship-of-series orders. Many drawings were issued just ahead of construction of the first bulker. However, for the construction of subsequent ships of like design, the measurement of welding length for use as a control parameter is planned for implementation, at least in some areas.

The flat panel line is a likely candidate for institution of standards based on measured welding lengths. This assembly shop performs work of a routine, repetitive nature for which a direct relationship exists between manhours (of fitters and welders) and welding length. However, another unique situation for Livingston is that panel line assembly was just recently installed in a shop location with a permanently organized layout. Therefore, data on manhours requires allowing for influence of the "learning curve".

2) Conversion from unit weight: This method proposed by IHI has merit due to its simplistic formula calculation made from available data. However, the data require verification through analysis of a shipyard's actual performance over a series of like vessels. Since Livingston has completed only the first F-32 type bulker at this time, the data have not been collected nor verified for application of this method. It is believed, however, that this method can have considerable value as a tool for calculating performance standards and cost standards.

The *control* parameters recommended by IHI for Livingston to use were listed in Table T6-2. Welding length was specified for the assembly and erection areas.

The location of work influences its efficiency and productivity. At IHI, assembly is performed in covered shops under controlled conditions. At Livingston, this work is performed both in the shop (Flat Panel Line) and on slabs outside. The measured welding length method, therefore, is applicable to the Panel Line while conversion coefficients, less accurate but easier to obtain, are more appropriate to assembly work on-slab.

In the Fabrication area, IHI recommended piece counts and tonnage as parameters for Livingston to use. The revised Bills of Material

(Figure 6-24) provide this information. Work orders issued at Livingston are written to correspond to the process gates through which a unit passes. Since manhours are charged against these Work Orders, Livingston plans to collect these data and use it as a basis for projecting efficiency on future work of similar type. This is the method that has been employed successfully by the Japanese and is applicable to U.S. shipbuilding activities.

Another way of accomplishing this objective is to issue forms to supervision similar to those of Figures 6-1 and 6-2. From the data collected on these forms, graphs and charts of efficiency and productivity can be produced by Industrial Engineering, similar to that shown on Figure 6-3. These charts will be displayed on blackboards such as the type proposed on Figure 6-4.

6.9 CONCLUSION

The main objective of the calculation of performance standards is for use in projecting accurate plans and schedules. The data collection methods proposed by IHI are planned for implementation at Livingston when a sufficient data base has been compiled. Probably the single most important factor in providing a system of useful performance standards is assuring that accurate data is reported. The standards are only as reliable as the data upon which they are based. This depends on accurate reporting by supervision and validated calculations by people knowledgeable of the processes and methodology of technical analysis.

The techniques used by IHI to measure performance by using statistical methods are known to U. S. industry as applications of Industrial Engineering. It is to the advantage of shipyards to apply these techniques to their facility using methods and parameters best suited to their particular needs.